MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Martin O'Malley, Governor
John R. Griffin, Secretary

Lower Western Shore
Water Quality and Habitat Assessment

Maryland Department of Natural Resources
Tidewater Ecosystem Assessment

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Information on the water and habitat quality of Maryland's rivers and bays is available due to the hard work of many dedicated staff including:

- staff who are in the field collecting the samples year-round, sometimes under less than desirable weather conditions
- laboratory staff who perform the chemical tests to determine what exactly is in those water samples
- data management staff who collect the resulting information, confirm the accuracy and quality of the data, and organize and maintain the databases and
- analytical staff who interpret the data to answer the question 'how is the river/Bay doing?'

There are too many individuals to directly name from more than 25 years of monitoring, so we simply wish to commend all of them for their commitment to collecting high quality information and making it available and useful to the citizens of Maryland.

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Overall Condition

Healthy rivers and bays support a diverse population of aquatic life as well as recreational uses, such as swimming and fishing. To be healthy, rivers and bays need to have good water and habitat quality. High levels of nutrients and sediments lead to poor water quality. Poor water quality reduces habitat quality, including water clarity (how much light can get to the bottom) and the amount of dissolved oxygen in the water. In turn, habitat quality affects where plants and animals can live. The Maryland Department of Natural Resources (DNR) is responsible for monitoring water and habitat quality in the Chesapeake Bay and rivers, as well as the health of aquatic plants and animals. DNR staff use this information to answer common questions like "How healthy is my river?", "How does my river compare to other rivers?", "What needs to be done to make my river healthy?" and "What has already been done to improve water and habitat quality in my river?"

How healthy are the Lower Western Shore Rivers?

Overall, the Lower Western Shore basin rivers have fair to poor water quality. Nitrogen levels are too high, but phosphorus and sediment levels are better than other similar rivers. Septic systems are the largest source of nitrogen in the northern basin. Runoff from urban areas is the largest source phosphorus and sediments loadings to the rivers. More than half of the upper basin is urban. Impervious surfaces cover more than 10% of the basin as a whole. Urban area increased 10% in the last decade, increasing the negative effects of runoff from these urban areas.

Habitat quality in the Lower Western Shore basin rivers is mixed but getting worse in some areas. Water clarity is poor, so not enough light can reach the bottom for underwater grasses to use. Dissolved oxygen levels differ among the rivers, but in all of the rivers bottom dwelling animal populations are in poor health.

Magothy River Water quality is fair though nitrogen levels are high. Septic systems are the largest source of nitrogen, and most of the phosphorus loads come from urban runoff and point sources. The largest source of sediments is urban runoff. Habitat quality is poor due to low water clarity and bottom dissolved oxygen levels. Water clarity has degraded over the last several decades, and healthy underwater grass populations are only found in very small areas in the river. Dissolved oxygen levels are very low in the summer so habitat quality for bottom dwelling animals is poor. Phytoplankton and bottom dwelling animals are not healthy.

Severn River Water quality is fair though nitrogen levels are high. Point sources are the largest source of nitrogen and phosphorus. Septic sources and urban runoff are also large sources of nitrogen. Habitat quality is poor due to low water clarity and bottom dissolved oxygen levels. There are fewer healthy underwater grass populations than five years ago, but the Severn River has more underwater grasses than the other rivers in the basin. Dissolved oxygen levels are very low in the summer so habitat quality for bottom dwelling animals is poor.

South River Water quality is fair though nitrogen and phosphorus levels are high. Septic systems are the largest source of nitrogen. Point sources are the largest source of phosphorus and sediments. Habitat quality is poor for underwater grasses and bottom dwelling animals. Water clarity has gotten worse over the last several decades even though sediment levels have improved over the last twelve years. No SAV beds have been found in the South River since 2005. Dissolved oxygen levels are very low in the summer so habitat quality for bottom dwelling animals is poor. Phytoplankton and bottom dwelling animals are not healthy in the South River.

Rhode River Water quality is fair though nitrogen and phosphorus levels are high. Agriculture is the largest source of sediments and phosphorus, while point sources are the largest source of nitrogen. Habitat quality is fair due to low water clarity, but no underwater grass beds have been found in the Rhode River since 1978. Dissolved oxygen levels and habitat quality are fair to good for bottom dwelling animals.

West River Water quality is fair though nitrogen and phosphorus levels are high. Agriculture is the largest source of sediments and phosphorus, while point sources are the largest source of nitrogen. Habitat quality is poor due to low water clarity, and no underwater grass beds have been found in the West River since 2004. Dissolved oxygen levels and habitat quality are fair to good but bottom dwelling animals are not healthy.

How do the Lower Western Shore Rivers compare to other Maryland rivers?

The Magothy, Severn and South Rivers are in the 'High Urban, Low Agriculture' land use category (Figure 1). Total N load and Total P load per acre are higher in the Magothy and Severn rivers than in most of the other Maryland rivers. Nitrogen, phosphorus and sediment levels are similar in all three rivers and low compared with other high urban systems (Figure 2). Algal density is also similar in all three rivers and moderate compared to other rivers. Water clarity is better than in other high urban systems, but summer bottom dissolved oxygen levels are among the worst of all Maryland rivers.

Rhode River is included as part of the West River watershed for land use assessments, so it is not separately comparable to the other Maryland rivers. The West/Rhode system is in the 'High Urban, High Agriculture' land use category. Total N load and Total P load per acre is moderate compared to other rivers. Nitrogen, phosphorus and sediment levels are lower than other rivers and algal levels are moderate compared with other rivers. Water clarity is lower in the West/Rhode rivers than in the other Lower Western Shore rivers, and summer bottom dissolved oxygen levels are much higher.

Table 1. Summary of tidal water quality and habitat parameters.
Algal densities, water clarity, inorganic phosphorus and sediments either ‘Meet’ or ‘Fail’ SAV habitat requirements (Appendix 5). Dissolved nitrogen levels below the level for nitrogen limitation ‘Meet’ criteria, otherwise ‘Fail’ criteria. Summer bottom dissolved oxygen levels above 3 mg/l ‘Meet’ criteria, otherwise ‘Fail’ criteria. Annual trends for 1999-2010 either ‘Increase’ or ‘Decrease’ if significant at $p \leq 0.01$ or ‘Maybe Increase’ or ‘Maybe Decrease’ at $0.01 < p < 0.05$; blanks indicate no significant trend. Improving trends are in green, degrading trends are in red. Nitrogen trends are for total nitrogen, phosphorus trends are for total phosphorus, water clarity trends are for Secchi depth. Depth ‘Shallow’ is from the shallow water monitoring program, ‘Open’ is from the long-term monitoring program.

River	Water Depths	Water Quality			Habitat Quality		
		Nitrogen	Phosphorus	Sediments	Algal densities	Water Clarity	Summer Bottom Dissolved Oxygen
Magothy	Shallow	Meet	Meet	Meet	Fail	Fail	Meet
	Open	Meet	Meet	Meet	Fail	Fail	Fail
Severn	Shallow	Meet	Meet	Meet	Fail	Fail	Meet
	Open	Meet	Meet Maybe Decrease	Meet Decrease	Fail	Fail	Fail
South	Shallow	Meet	Meet	Meet	Meet	Fail	Meet
	Open	Meet	Meet Maybe Decrease	Meet Decrease	Fail	Fail	Fail
Rhode	Shallow	Meet	Meet	Meet	Meet	Fail	Meet
	Open	Meet	Meet	Meet	Fail	Fail Maybe Decrease	Meet
West	Shallow	Meet	Meet	Meet	Meet	Fail	Meet
	Open	Meet	Meet	Meet	Fail	Fail	Meet

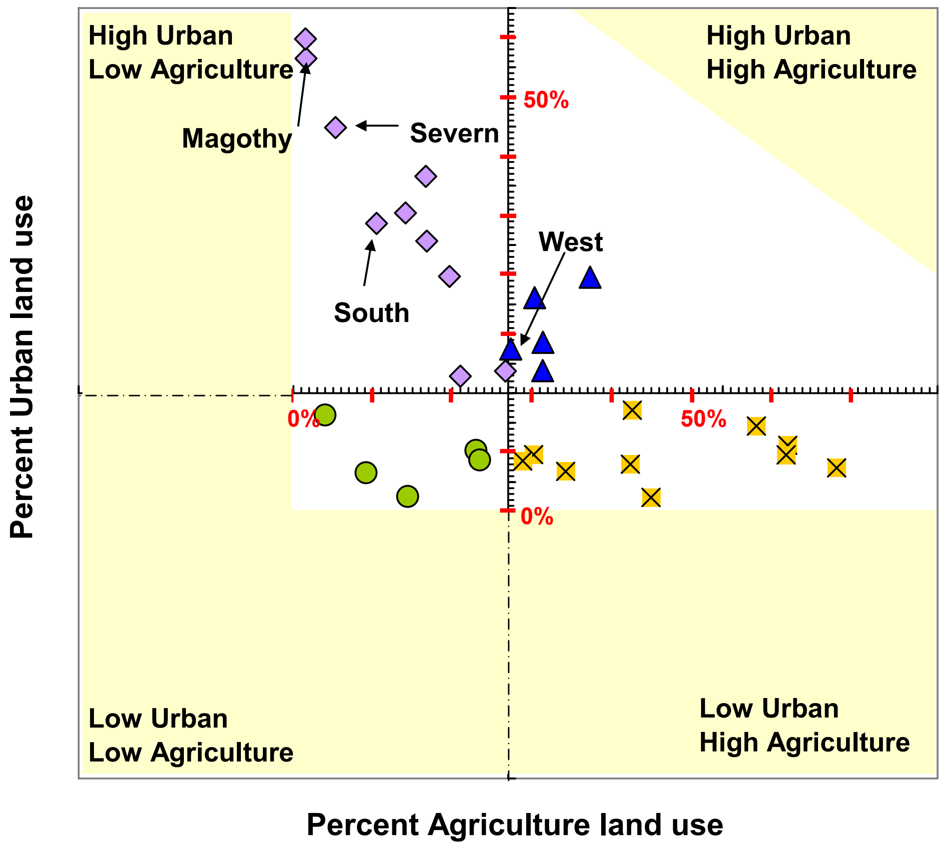

Figure 1. Classification of Maryland rivers and bays by land use.
The medians of all systems percent agriculture and percent urban land use are used to create a grid with four categories. Systems with percent urban less than the median are considered low urban. Systems with percent agriculture less than the median are considered low agriculture. Each system was categorized based on placement on the grid. Note that yellow areas are not mathematically possible (i.e. there is not a negative percent agriculture land use, and it is not possible for percent agriculture + percent urban to be greater than 100%). These groupings were used to evaluate each system relative to other rivers with similar land use characteristics. Rhode River is included as part of the West River watershed for land use assessments, so it is not separately comparable to the other Maryland rivers.

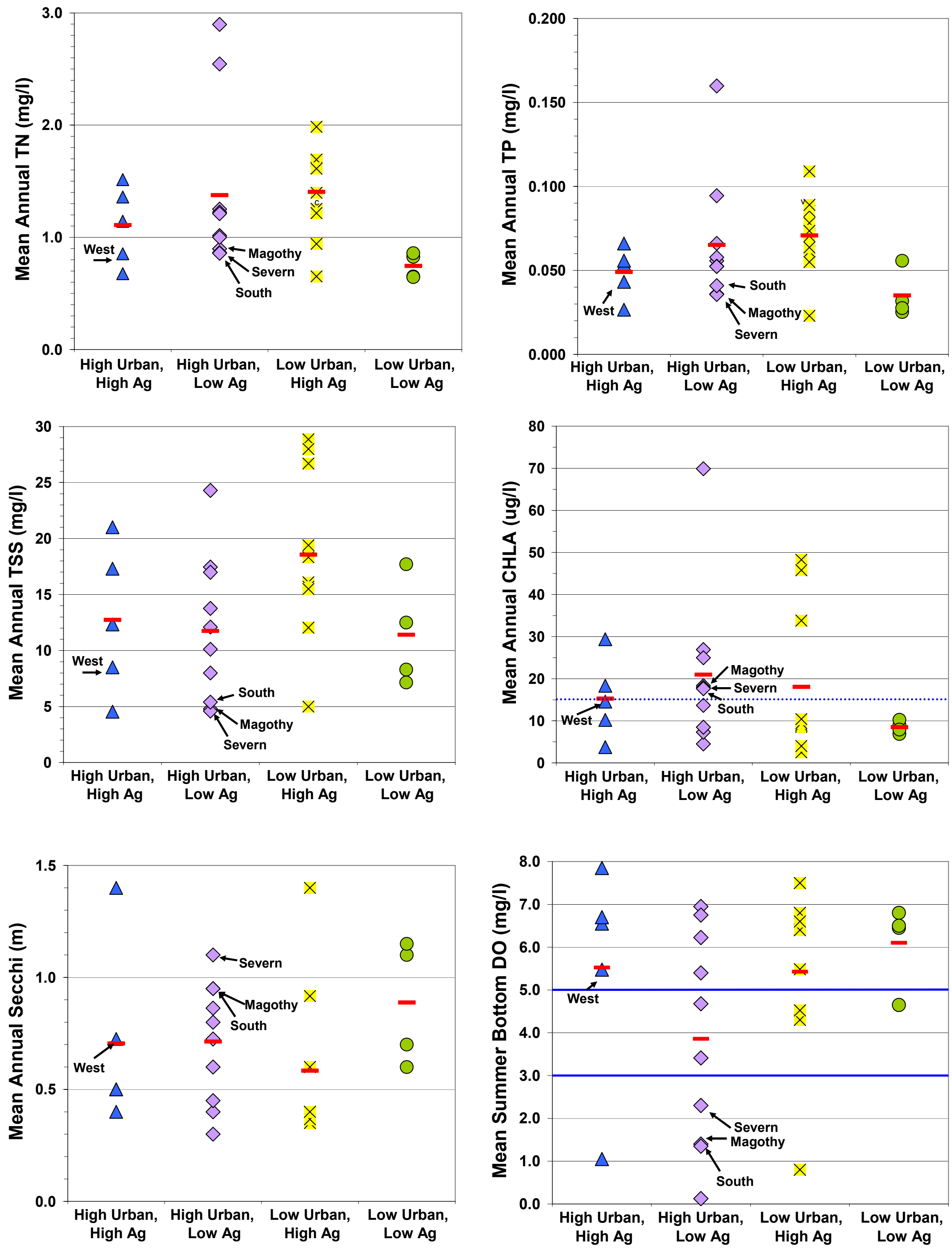

Figure 2. Comparison of the Lower Western Shore Rivers to similar systems.
The mean annual concentration or depth (bottom dissolved oxygen is only summer) for 2008-2010 data. Red bars indicate the mean of all systems within a category. Reference lines are included on the CHLA and BDO graphs. Rhode River is included as part of the West River watershed for land use assessments, so it is not separately comparable to the other Maryland river systems.

What needs to be done to make the Lower Western Shore Rivers healthy?

Even though nutrient and sediment levels are meeting underwater grasses habitat requirements in all of the rivers, habitat is degraded by poor water clarity and high algal densities. Low dissolved oxygen levels in the Magothy, South and Severn rivers are further degrading habitat in those rivers. The disconnect between water quality and habitat quality is likely the result of seasonal differences in DIN levels and algal densities. Algal populations use DIN to fuel growth. DIN levels peak in the winter and early spring along with the river flow for the year (in most years). The higher the DIN levels in the spring, the greater the algal population can increase. As the result of this growth, DIN is used up and summer DIN levels are low. So, while DIN levels are low in the summer, the high algal densities indicate that nitrogen levels are still too high in the rest of the year, especially in the winter and spring. Actions that reduce nitrogen loadings need to be a priority. These nitrogen reduction methods need to address loads from septic systems in the northern basin. Reducing algal densities by reducing nitrogen will also increase dissolved oxygen conditions and improve habitat for bottom living animals.

Sediment levels are declining and water quality is improving. Continued reductions in sediment loads will contribute to improved water clarity. Sediment load reduction actions should target urban runoff sources in the northern basin and agricultural sources in the southern basin. As more land is converted from agriculture to urban uses in the southern basin, management actions should address urban runoff in the entire basin. It is most likely that urban areas will continue to increase, so methods to reduce impervious surface coverage become even more necessary. Alternatives to conventional development methods should be used to reduce the amount of impervious surfaces and prevent degradation of water quality in the West and Rhode rivers.

Phosphorus levels may be declining, and continued reductions in phosphorus loads will also lead to improving water quality. Phosphorus load reductions should target urban runoff in the upper basin and point source loadings to the Severn River.

What has already been done to improve water and habitat quality in the Lower Western Shore Rivers?

A variety of actions have already been taken to lower nitrogen, phosphorus and sediment loadings, and the excessive nitrogen levels in the tidal waters. To reduce nutrient inputs from urban lands, these actions include upgrades to wastewater treatment plants, managing stormwater runoff and retrofitting septic systems. While specific goals have not been set for this basin, improvements are being made. Upgrades to the major wastewater treatment plants in this basin are under construction and will be completed by 2014. Stormwater retrofits have reduced nitrogen loadings and prevented nearly 8,000 pounds of nitrogen from entering the rivers since 2003, and more than 200 septic system retrofits were completed between 2008-2010.

To address nutrient inputs from agricultural lands, additional management actions have been taken. In 2010 there were 330 acres of cover crops planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on over 700 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. More than 250 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands.

Maryland also has a number of programs in place to reduce the impacts of continued development and increasing amounts of impervious surfaces in the Lower Western Shore basin. Rural Legacy Program projects have protected approximately 800 acres, with special focus on areas with important cultural sites and natural resources and to ensure large areas of habitat. Maryland Environmental Trust projects have helped individual land owners protect approximately 1,500 acres. Maryland Agricultural Land Preservation Program projects have preserved almost 200 acres of agricultural land from development.

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Introduction

Water quality is measured as the level of nutrients and sediments in the water. Habitat quality is determined by how nutrients and sediments impact water clarity, algal populations and bottom dissolved oxygen levels. Habitat quality is also determined by salinity and water temperatures, but these measures are not changed by nutrients and sediments. Habitat quality determines if and where underwater grasses, fish and bottom dwelling animals can live. Reducing the levels of nutrients and sediments is a major focus of restoration efforts. The goal is to reduce nutrient and sediment levels so that habitat quality is improved and high quality habitat is expanded. Assessing water and habitat quality is an important first step in making decisions on what needs to be done to improve water and habitat quality.

Habitat quality can be assessed by looking at the health of the aquatic plants and animals that remain in the same location, such as underwater grasses and bottom dwelling animals. The health of these organisms depends on habitat that is suitable for growth and survival, so healthy organisms indicate healthy habitats. Changes in the populations of these plants and animals can often be linked to specific parts of habitat quality that are poor, such as water clarity or bottom dissolved oxygen. This additional information helps managers better pinpoint what needs to be changed to improve water and habitat quality.

Land use in a watershed is linked to the human population density. Rivers with high urban land uses have higher population densities and more impervious surfaces. Rivers with high agricultural land uses in rural areas have lower population densities and less impervious surfaces. Higher population densities are often linked to management of human wastes through wastewater treatment plants, while septic systems are more prevalent in areas with lower population density. Pollutant loadings from undeveloped lands such as forests are different from loadings from more developed areas. Information on human population and land use help managers decide the best methods for reducing nutrients and sediments going from the land into the water.

The Lower Western Shore Water and Habitat Quality Assessment includes a variety of information. Land use data and census data are examined to understand how the watersheds are impacted by human uses. Loadings data is examined to identify how much nutrient and sediment is entering the non-tidal streams from the watershed. Data from the long-term tidal water quality monitoring program are examined for current water and habitat quality and changes over time. Data from monitoring in shallow water habitats are examined to determine water and habitat quality in the areas most important for underwater grasses and the organisms that live there. Data from monitoring of algal populations, underwater grasses and bottom dwelling organisms are examined to determine how well the resulting habitat quality supports healthy plant and animal populations.

Land use and Human population

The Lower Western Shore basin includes land in Anne Arundel County surrounding the Magothy, Severn, South, Rhode, and West Rivers, and a section of Calvert County adjacent to the Chesapeake Bay mainstem. The Lower Western Shore basin drains approximately 300 square miles in five sub-watersheds (Figure 3). The entire basin lies in the Coastal Plain

Province. In many areas near tidal waters, the hill-terrain forms cliffs along the shoreline. Because of low elevations in the basin, surface waters generally flow sluggishly in winding courses, often through wetlands before reaching the Bay. Larger cities include Annapolis and Chesapeake Beach.

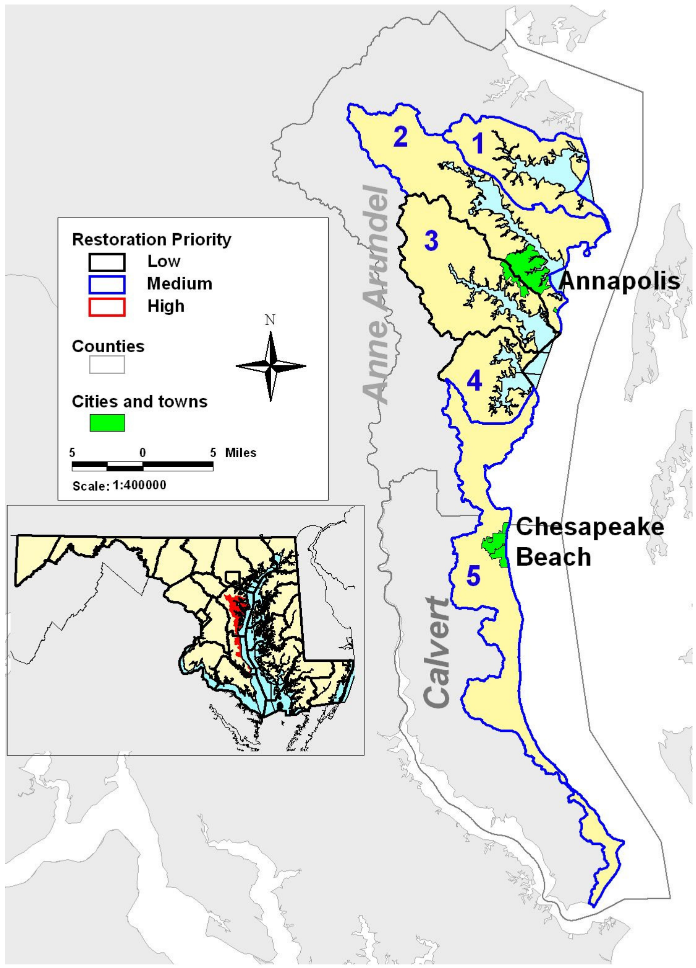

Figure 3. Lower Western Shore basin.
Trust Fund Priority Watershed Restoration Priority designation (high, medium, low), county lines and cities/towns are shown. Sub-watersheds (8-digit) are: 1- Magothy River, 2- Severn River, 3 – South River, 4- West River, and 5- West Chesapeake Bay.

In 2010 there were approximately 300,000 people living in the watershed[1]. Population density in the upper basin was 1,000-10,000 people per square mile in areas adjacent to the Magothy, Severn and South Rivers, including the city of Annapolis, and in the upper portion of the Severn River watershed (Figure 4). Another small area of higher density population was in the lower basin in the area of Chesapeake Beach. The remainder of the basin had a lower population density (100-1,000 people mi^2).

[1] 2010 data from the U.S. Census Bureau available online at http://www2.census.gov/census_2010/04-Summary_File_1/

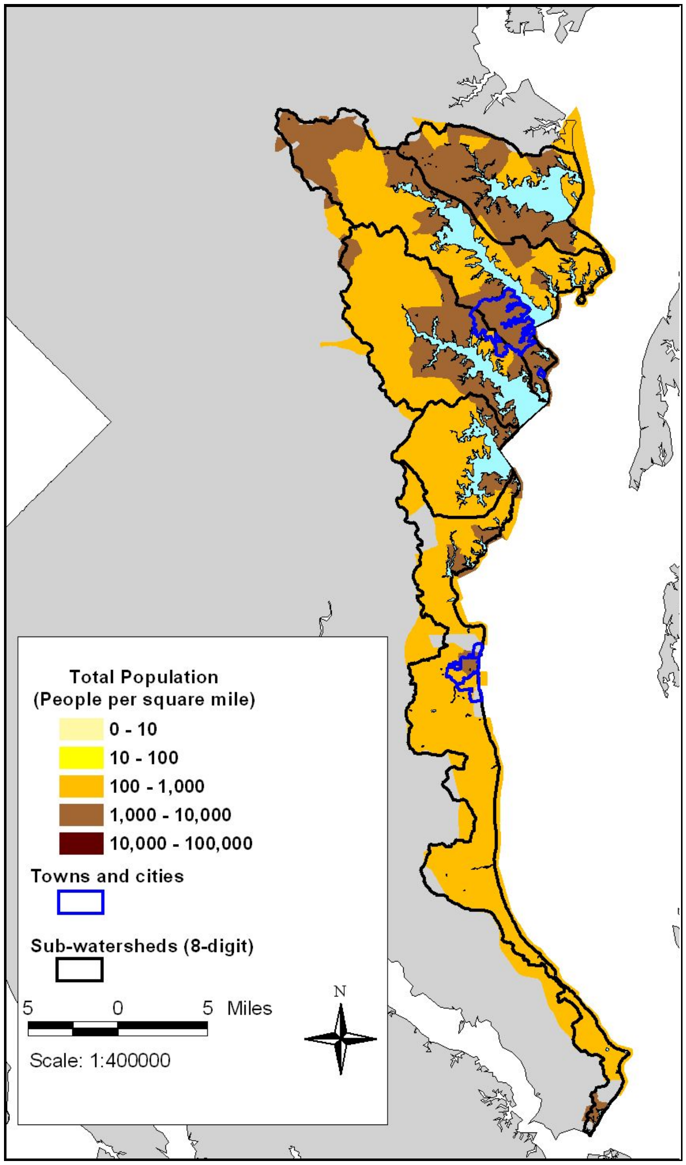

Figure 4. Lower Western Shore basin 2010 Census data for total population by block group. Total population per square mile is shown using a log scale. Differences between the watershed boundaries and the Census bureau block groups boundaries result in non-exact matching of the population data to the watershed.

In 2010, the largest land use in the Magothy River, Severn and South River watersheds was urban (Appendix 1).[2] Urban land use increase by more than 9% in each of the three watersheds from 2000 to 2010 (Figure 5). Forested areas decreased in these watersheds, and agricultural land use was reduced in the Severn and South watersheds over the same time period. Impervious surface was greatest in the Magothy River watershed (18%) and greater than 10% in the Severn and South River watersheds (16% and 11%).[3]

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[2] Maryland Department of Planning data for 2010 available at www.planning.maryland.gov/OurWork/landUse.shtml

[3] Percent impervious surfaces greater than 10% typically lead to impaired water and habitat quality.

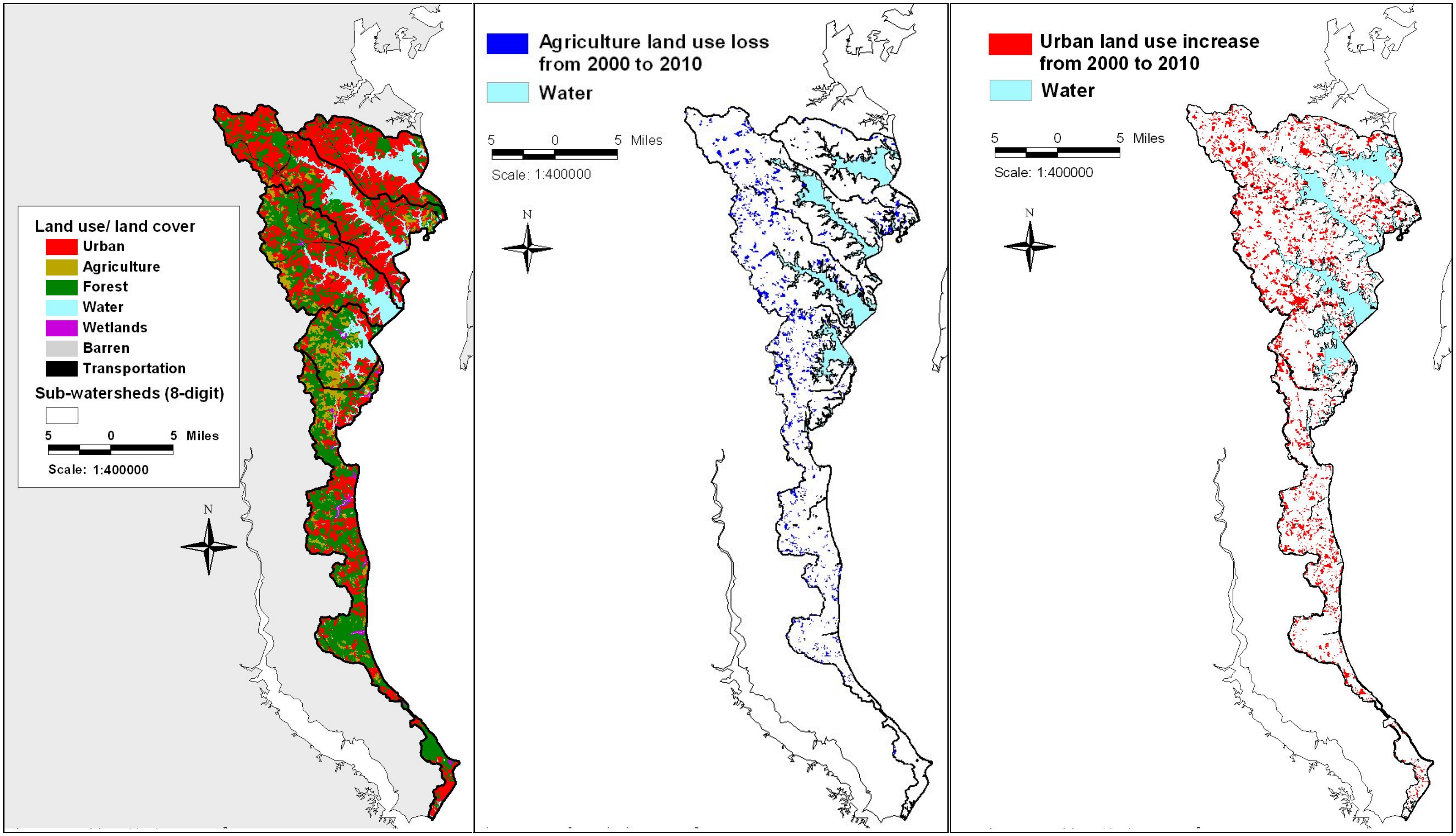

Figure 5. Lower Western Shore basin land use/land cover data for 2010.
See Appendix 1 for detailed land use/land cover information. Left Panel shows all land use categories for 2010. Middle Panel shows change in agricultural land use from 2000 to 2010. Right panel shows change in urban land use from 2000 to 2010.

The West River watershed (also including the Rhode River) was about two-fifths forested in 2010, and approximately one-fourth urban and agricultural. Urban land use in the West River watershed increased by 9% from 2000 to 2010, and agricultural land use declined by the same amount. Impervious surface was 5% in the West River watershed. Half of the West Chesapeake Bay watershed was still forested in 2010, but urban land use was 35% of the entire watershed, an increase of 10% from 2000. Impervious surface covered 6% of the West Chesapeake Bay watershed.

Stream health in the Lower Western Shore watersheds is categorized as poor except for the Severn River watershed where stream health is considered fair[4]. The Magothy River, South River and Western Chesapeake Bay watersheds are medium priority watersheds for Maryland Trust Fund restoration efforts[5].

Maryland has a number of programs in place to reduce the impacts of continued development and increasing amounts of impervious surfaces in the Lower Western Shore basin. Rural Legacy Program projects have protected approximately 800 acres, with special focus on areas with important cultural sites and natural resources and to ensure large areas of habitat. Maryland Environmental Trust projects have helped individual land owners protect approximately 1,500 acres. Maryland Agricultural Land Preservation Program projects have preserved almost 200 acres of agricultural land from development.

Nutrient and Sediment Loadings

In accordance with the Chesapeake Bay Total Maximum Daily Load (TMDL), Maryland has developed a Watershed Implementation Plan (WIP) for making reductions in nitrogen, phosphorus and sediment loads to the Chesapeake Bay.[6] Maryland is required to reduce loads to Final Target loads by 2025. Maryland's Interim Target loads are set at 60% of the Final Target loads by 2017. Progress toward these Interim and Final Target loads is further broken into 2-year milestone loads. The first of these 2-year milestones is set for July 1, 2011- June 30, 2013.[7]

The rivers in the Lower Western Shore basin are combined with the Patapsco, Back and Upper Western Shore basin rivers into a single category- the Western Shore Basin. Final Target Loads for the Western Basin are 9.77 million pounds per year of nitrogen, 0.55 million pounds per year of phosphorus and 243 million pounds per year of sediments. The information below is loadings in 2009.

[4] Maryland Department of Natural Resources data available at www.streamhealth.maryland.gov/stream_health.asp
[5] Information on Maryland's Trust Fund is available at http://www.dnr.maryland.gov/ccp/funding/pdfs/TrustFundPriorities.pdf
[6] Maryland's Phase II Watershed Implementation Plan is online at www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/FINAL_PhaseII_WIPDocument_Main.aspx
[7] Progress toward meeting the 2011-2013 milestones is available on BayStat at www.baystat.maryland.gov/milestone_information.html

Overall, the Lower Western Shore received approximately 1 million lbs/yr nitrogen, 0.1 million lbs/yr phosphorus and 10.6 million lbs/yr of sediments (Appendix 2). Septic and urban runoff accounted for most of the nitrogen loadings to the Magothy, Severn and South Rivers (Figure 6). Point sources were also an important source of nitrogen to the Severn. Phosphorus loadings to the Magothy, Severn and South Rivers were mostly from urban and point sources (septic is not considered a source of phosphorus). Urban runoff was the dominant source of sediments to these three rivers. Forest sources and agriculture also contributed to the sediment loadings.

Nitrogen loadings to the Rhode River were dominated by point sources, and agriculture and forest sources were also important. Agriculture, point sources and urban runoff are the main sources of phosphorus to the Rhode River, while sediment loadings came from agriculture, forest and urban runoff. For the West River, agriculture was the largest source of nitrogen, phosphorus and sediments. Nitrogen loadings to the West River from forest and septic and phosphorus loadings from point sources were also important.

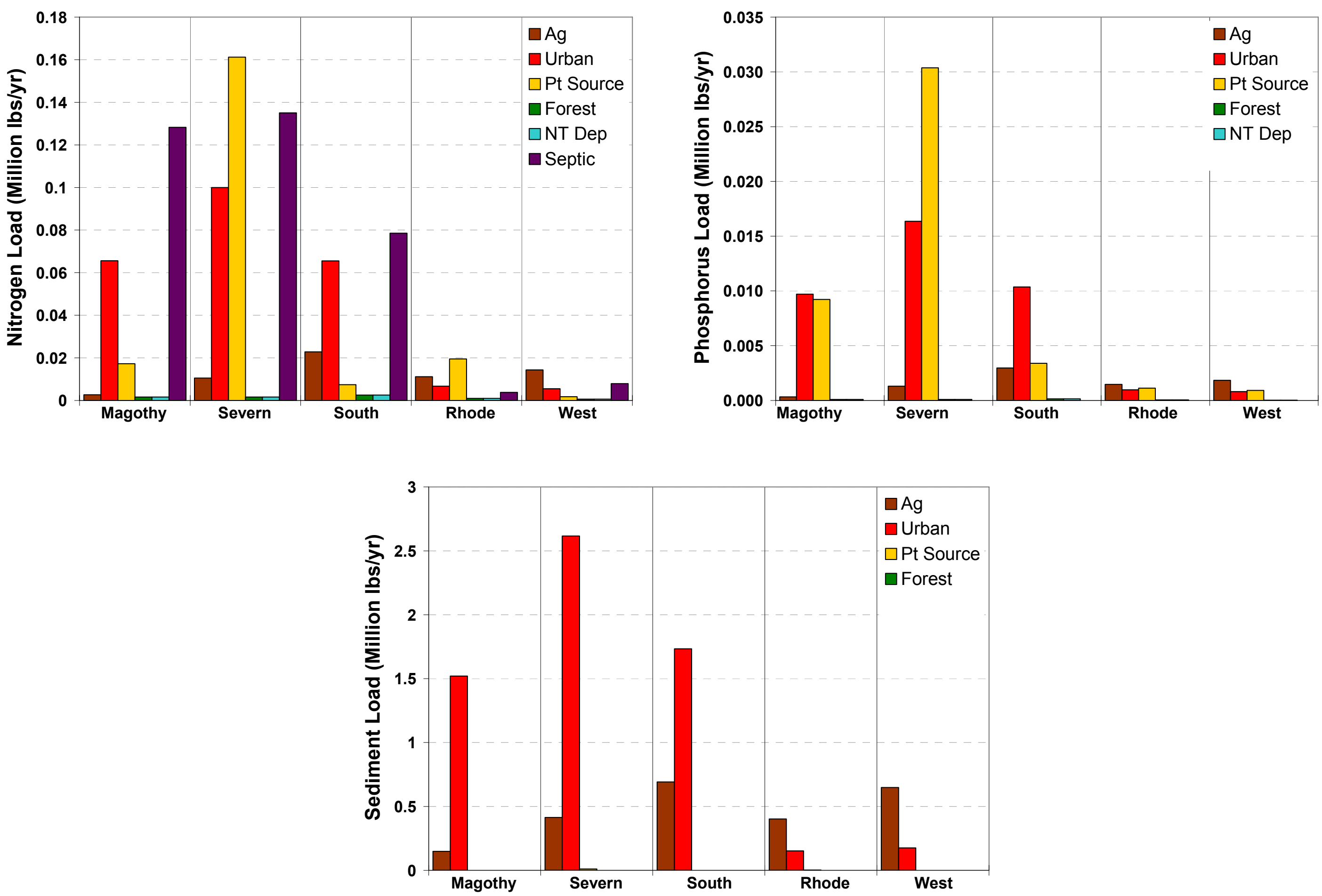

Figure 6. Nitrogen, phosphorus and sediment loadings per year.
Delivered loadings by category in million lbs/yr (see Appendix 2). Septic is not a source of phosphorus or sediment loadings and water deposition (NT Dep) is not a source of sediment loadings.

Point Source Loads

Nutrient loadings from point sources (including wastewater treatment plants, WWTPs) are the easiest to measure. Point source loads are often the most cost-effective to manage. A major focus of management actions to reduce nutrient loads has been upgrades to WWTPs. In 2004 Maryland passed legislation creating the Chesapeake Bay Restoration Fund specifically to fund WWTP upgrades to enhanced nutrient removal (ENR).[8] The program is working to complete ENR upgrades to 67 major WWTPs, including six facilities in the Lower Western Shore basin.[9] None of these upgrades were complete by the end of 2010.

Point sources (including wastewater treatment plants) were important to the phosphorus loadings to the Magothy, South and Severn rivers, and to nitrogen loadings in the Severn and Rhode rivers. The Lower Western Shore Basin has six major WWTPs. The Mayo WWTP discharges into the Rhode River. The other five WWTPs (Chesapeake Beach, Broadneck, Pine Hill Run and Annapolis) discharge directly to the mainstem Chesapeake Bay. Construction of ENR upgrades to the Mayo WWTP are planned to begin by the end of 2012 and be complete by the end of 2014.[10] ENR upgrades are also under construction at the other WWTPs and expected to be completed by 2013-2014. Nitrogen loadings from the Mayo WWTP have fluctuated independent of the increase in flow from 1989-2010, but phosphorus loadings are much lower than peaks from 1991-1994 (Figure 7).

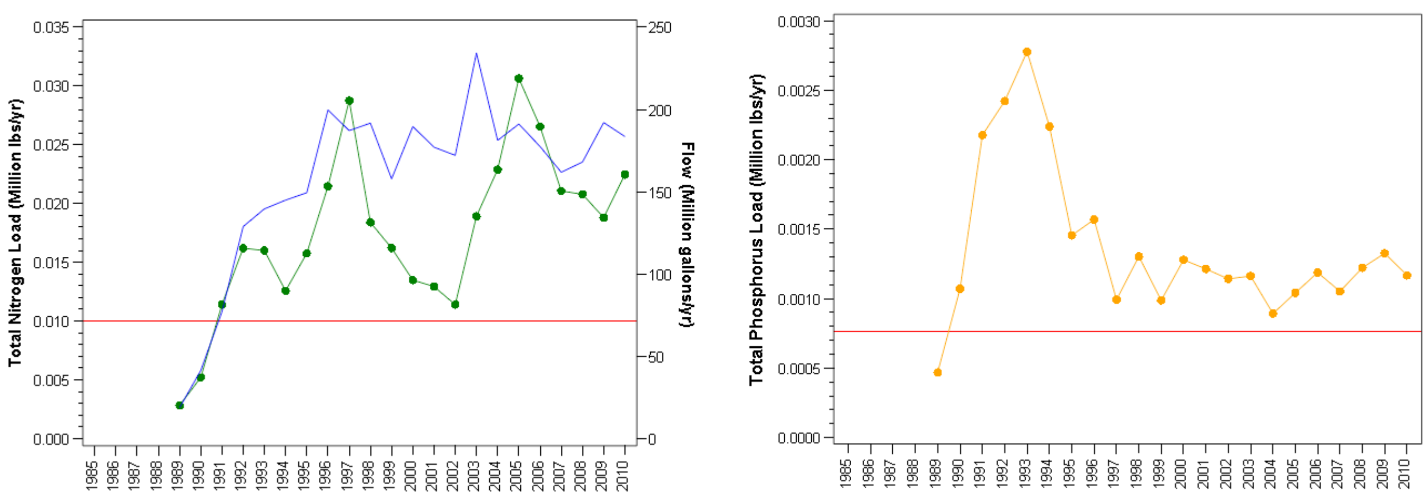

Figure 7. Annual total nitrogen and total phosphorus loadings and effluent flow from Mayo WWTP to the Rhode River.
Blue line on nitrogen graph shows total annual effluent flow. Red horizontal line indicates the loading cap for the facility following implementation of ENR. The dotted vertical line indicates when BNR was implemented.

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[8] The Chesapeake Bay Restoration Fund collects fees from wastewater treatment plant users to pay for the upgrades. A similar fee is paid by septic system users to upgrade onsite systems and implement cover crops to reduce nitrogen loading to the Bay. For more information on the Chesapeake Bay Restoration Fund see http://www.mde.state.md.us/programs/Water/BayRestorationFund/Pages/index.aspx.
[9] Major wastewater treatment plants (WWTP) are those with greater than 0.5 million gallons per day (MGD) design flow.
[10] ENR reduces nitrogen concentrations to below 3 mg/l and phosphorus concentrations to below 0.3 mg/l in effluent.

Non Point Source Loads

In 1998, Maryland passed the Water Quality Improvement Act, which requires farmers to reduce nitrogen and phosphorus loadings from agricultural lands.[11] Soil Conservation and Water Quality Plans (SCWQPs) are developed to determine what the appropriate actions, or best management plans (BMPs), are for a given area.[12] Each of Maryland's counties has a Soil Conservation District Office with staff to help farmers develop and implement SCWQPs. The total number of BMPs in place in the basin as a whole (not by individual farm) is used to measure progress.[13] In 2010 there were 330 acres of cover crops planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on over 700 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. More than 250 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands.

Water and Habitat Quality

Tidal water quality monitoring is done year-round at three stations that have been monitored since 1985 in the Lower Western Shore rivers: Magothy, Severn, South, Rhode and West rivers (Figure 8, Appendix 3).

The following parameters were evaluated to assess water and habitat quality: total nitrogen (TN), total phosphorus (TP) , total suspended solids (TSS), dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (PO_4), algal abundance (as measured by chlorophyll *a*, CHLA), water clarity (as measured with a Secchi disc and by calculating the percent light through water, PLW), summer bottom dissolved oxygen (BDO), salinity and water temperature.

Assessment methods are described in Appendix 4. Selected graphical results are included with the text. Tidal water quality trends results discussed in the text refer to the 1999-2010 trends. Seasons for 1999-2010 trends are: spring (March-May), summer (July-September)[14] and SAV growing season (Apr-October). Significant trends for 1985-2010 are noted in the footnotes. Figure and Appendix references apply to all rivers and are given only the first time referenced. Summary results are presented in Table 1 in the 'Overall Assessment' section. Detailed tabular results are included in Appendices 6 and 7.

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[11] For more information, please see the Maryland Department of Agriculture website http://mda2.maryland.gov/resource_conservation/Pages/nutrient_management.aspx

[12] For more information see http://mda.maryland.gov/pdf/scwqplan.pdf

[13] Progress on different BMPs is available at http://www.baystat.maryland.gov/milestone_information.html

[14] For summer bottom dissolved oxygen analysis, the months used are June-September.

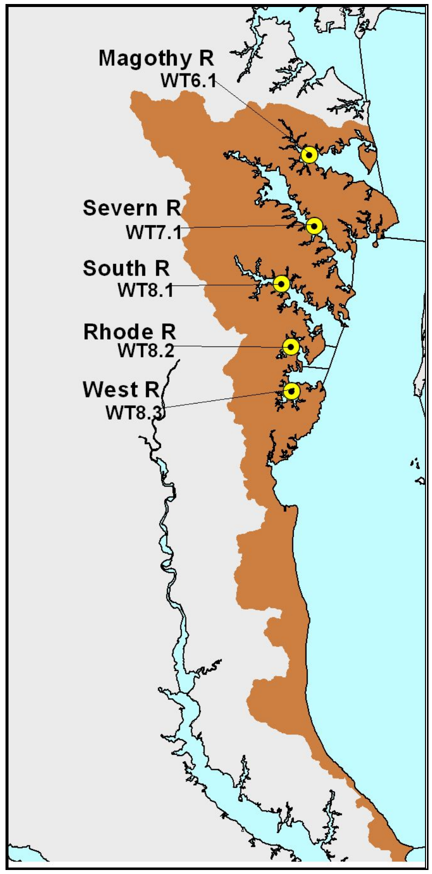

Figure 8. Long-term tidal water quality monitoring stations.

Tidal Rivers

Magothy River

TN in the Magothy River was relatively poor and DIN levels were relatively good (Figure 9).[15] Summer DIN levels were low enough that nitrogen limitation of algal growth likely occurred in most years and occasionally fall DIN levels were low enough to be limiting (Figure 10). The TN:TP ratio increased and the DIN:PO_4 ratio may have increased and indicates excess nitrogen relative to phosphorus.

TP in the Magothy River was relatively good. PO_4 was relatively good and may have improved. Median PO_4 levels for the SAV growing season were low enough to meet the habitat requirement (Figure 11). TSS levels were relatively good and may have improved.[16] TSS levels met the SAV habitat requirements.

Algal abundance and water clarity were both relatively poor and failed to meet the SAV habitat requirements (Figure 12).[17] Summer BDO levels were poor, predominantly below 3 mg/l and almost always below 5 mg/l (Figure 13).

[15] TN improved from 1985-2010.
[16] TSS degraded from 1985-1997.
[17] CHLA and Secchi depth degraded from 1985-2010

Severn River
TN in the Severn River was relatively poor and DIN levels were relatively good. Summer DIN levels were low enough that nitrogen limitation of algal growth likely occurred in most years. The TN:TP ratio increased and the DIN:PO_4 ratio may have increased and indicate excess nitrogen relative to phosphorus.

TP in the Severn River was relatively good and may have improved annually an in the SAV growing season. PO_4 was relatively good and median PO_4 levels for the SAV growing season were low enough to meet the habitat requirement. TSS levels were relatively good and improved annually and in the SAV growing season and may also have improved in the spring and summer.[18] TSS levels met the SAV habitat requirements.

Algal abundance was relatively poor and median CHLA levels for the SAV growing season do not meet the habitat requirement.[19] While nitrogen limitation may have occurred in the summer, algal abundance was not reduced to low levels. Water clarity was poor and borderline for meeting SAV habitat requirements. Summer BDO levels were fair, almost always below 5 mg/l and below 3 mg/l about half of the time. Salinity may have declined in the spring. There were no trends in water temperature.

South River
TN in the South River was relatively poor. DIN levels were relatively good but degraded in the spring.[20] Summer DIN levels were low enough that nitrogen limitation of algal growth likely occurred in most years. Nitrogen limitation also likely occurred in the fall, and may occasionally occur in winter and spring. The TN:TP ratio increased and indicates excess nitrogen relative to phosphorus. The DIN:PO_4 ratio also increased but indicates that nitrogen and phosphorus are more in balance.[21]

TP in the South River was relatively fair and may have improved. PO_4 was relatively good and median PO_4 levels for the SAV growing season were low enough to meet the habitat requirement. TSS levels were relatively good and improved annually and may have improved in the SAV growing season. TSS levels met the SAV habitat requirements.

Algal abundance was relatively poor and median CHLA levels for the SAV growing season were above the habitat requirement. While nitrogen limitation may have occurred in the summer, algal abundance was not reduced to low levels or to lower levels than when nitrogen was not limiting. Water clarity was poor and failed to meet the SAV habitat requirement.[22] Summer BDO levels were poor, always below 5 mg/l and predominantly below 3 mg/1. Salinity may have declined in the spring and there were no trends in water temperature.[23]

[18] Severn River TSS degraded from 1985-1997.
[19] Severn River CHLA may have improved from 1985-1997 but also may have degraded for 1985-2010.
[20] South River DIN levels degraded annually from 1985-1997.
[21] South River DIN:PO_4 ratio averaged 17:1 for 2008-2010, close to the Redfield ratio of 16:1.
[22] South River Secchi depth degraded from 1985-2010.
[23] South River salinity may have declined annually from 1985-2010.

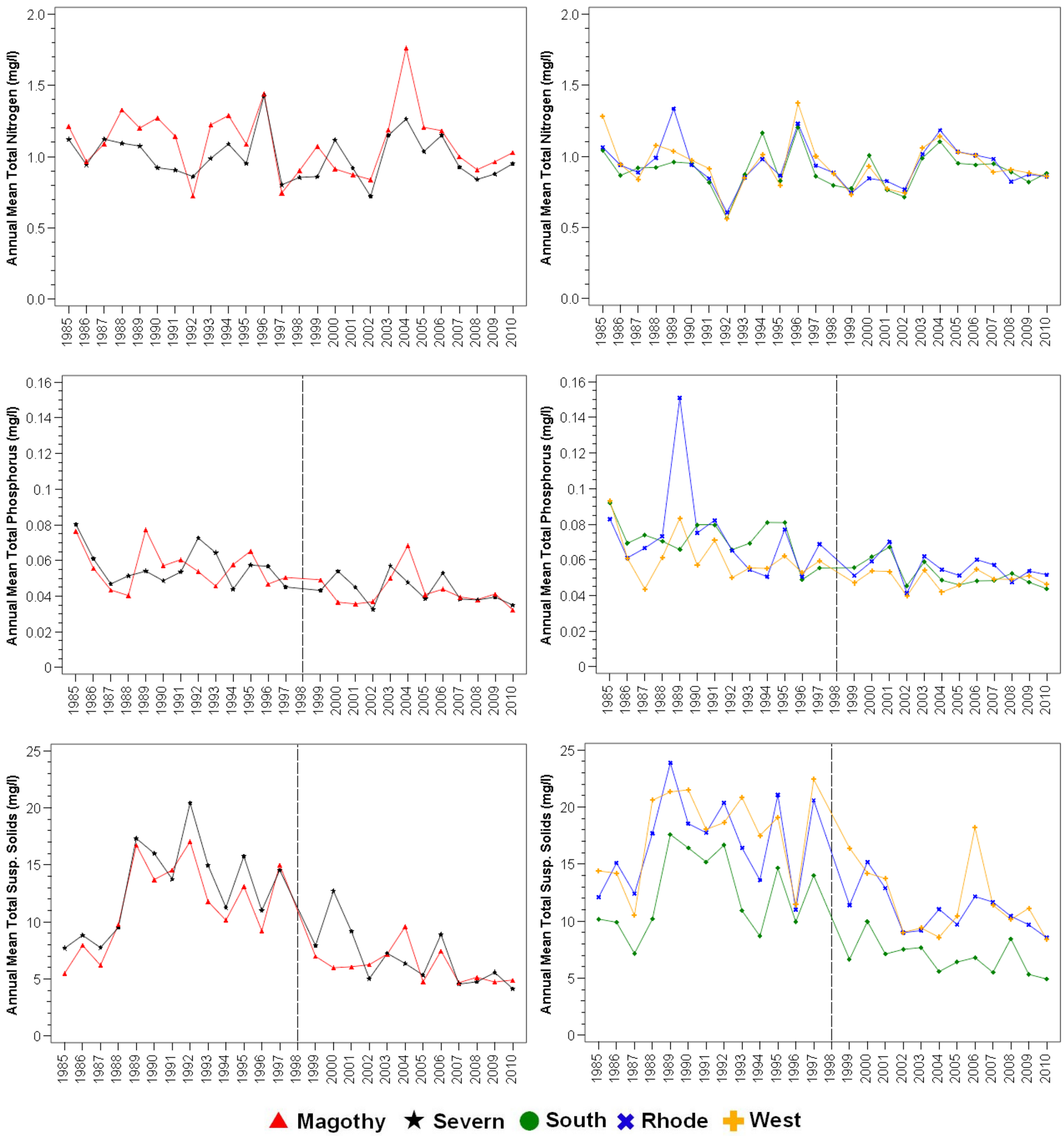

Figure 9. Annual means for total nitrogen, total phosphorus and total suspended solids. Left panels show data for the Magothy and Severn rivers. The right panels show the data for South, Rhode and West rivers. Dotted line (1998) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change.

Rhode River

TN in the Rhode River was relatively poor. DIN levels were relatively good but may have degraded annually and in the spring.[24] Summer DIN levels were low enough that nitrogen limitation of algal growth likely occurred in most years. Nitrogen limitation also likely occurred in the fall, and may occasionally occur in winter and spring. TN:TP ratio may have increased and indicates excess nitrogen relative to phosphorus. The DIN:PO_4 ratio increased but indicates that nitrogen and phosphorus are more in balance.[25]

TP was relatively fair and PO_4 was relatively good. Median PO_4 levels for the SAV growing season were low enough to meet the habitat requirement. TSS levels were relatively fair and median TSS levels met the SAV habitat requirements.

Algal abundance was relatively poor.[26] Median CHLA levels for the SAV growing season met the habitat requirement in most years, though not in 2010. While nitrogen limitation may have occurred in the summer, algal abundance was not reduced to low levels or to lower levels than when nitrogen was not limiting. Water clarity was poor and degraded in the summer.[27] Secchi may also have degraded annually and in the SAV growing season. Water clarity did not meet SAV habitat requirements. Summer BDO levels were good.[28] Summer BDO levels fall below 5 mg/l about half of the time, but only rarely fall below 3 mg/l. There were no trends in salinity or water temperature.[29]

West River

TN in the West River was relatively poor. DIN levels were relatively good and summer DIN levels were low enough that nitrogen limitation of algal growth likely occurred in most years.[30] Nitrogen limitation also likely occurred in the fall, and may have occasionally occurred in winter and spring. The TN:TP and the DIN:PO_4 ratios may have increased and indicate excess nitrogen relative to phosphorus.

TP was relatively poor and PO_4 was relatively good. Median PO_4 levels for the SAV growing season were low enough to meet the habitat requirement. TSS levels were relatively good and median TSS levels met the SAV habitat requirements.

Algal abundance was relatively poor.[31] Median CHLA levels for the SAV growing season met the habitat requirement in most years, but not in 2009. While nitrogen limitation may have occurred in the summer, algal abundance was not reduced to low levels. Water clarity was poor and may have degraded in the SAV growing season.[32] Water clarity did not meet SAV habitat requirements. Summer BDO levels were good, though oxygen levels frequently fell below 5 mg/l, but only rarely below 3 mg/l. There were no trends in salinity or water temperature.[33]

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[24] Rhode River DIN levels degraded from 1985-1997.
[25] Rhode River DIN:PO_4 ratio averaged 19:1 for 2008-2010, close to the Redfield ratio of 16:1.
[26] Rhode River CHLA may have degraded from 1985-2010.
[27] Rhode River Secchi depth degraded from 1985-2010.
[28] Rhode River Summer BDO levels may have degraded from 1985-2010.
[29] Rhode River salinity declined from 1985-1997 and may have declined from 1985-2010.
[30] West River DIN levels degraded from 1985-1997.
[31] West River CHLA may have degraded from 1985-2010.
[32] West River Secchi depth degraded from 1985-2010.
[33] West River salinity declined from 1985-1997 and may have declined from 1985-2010.

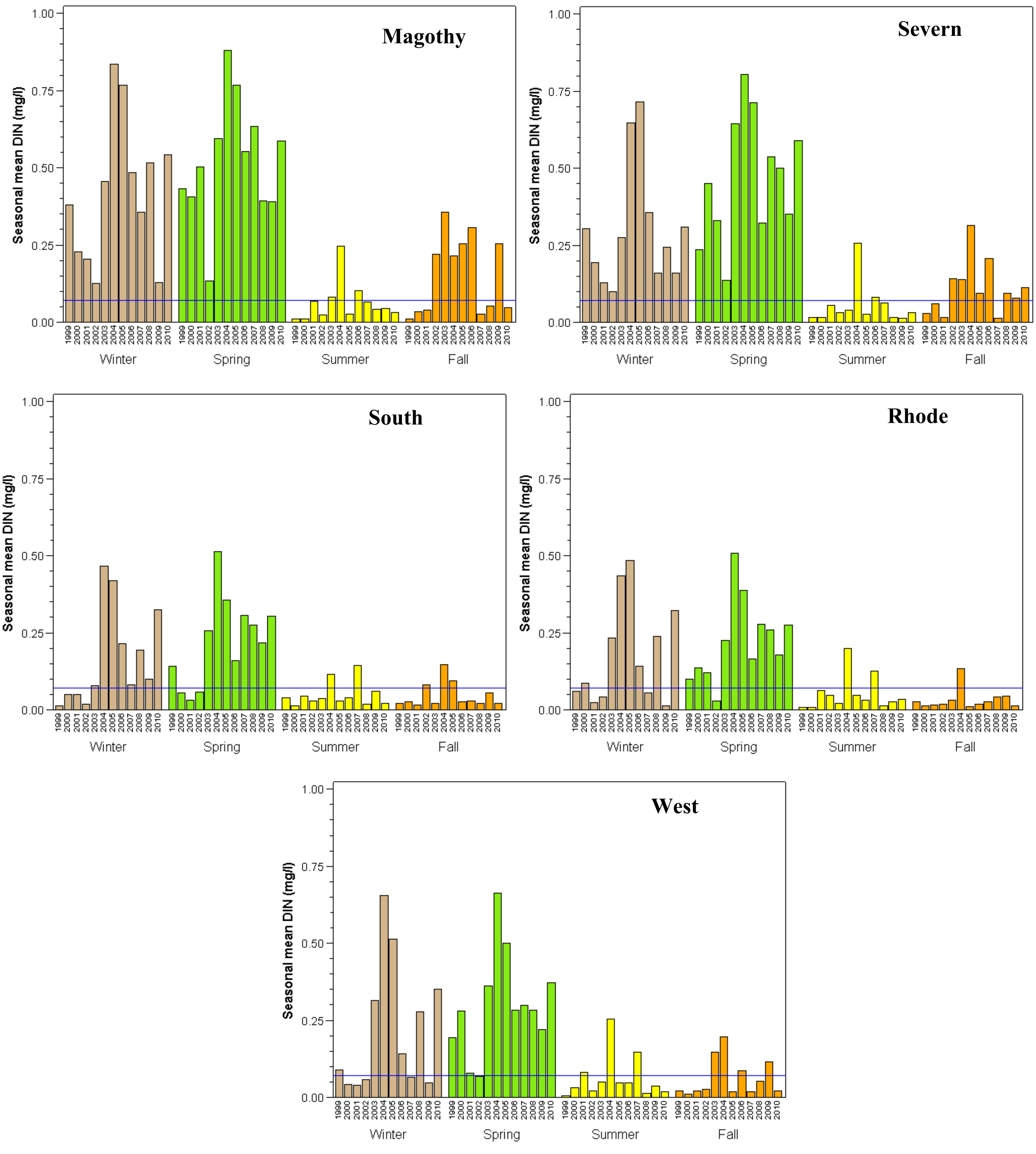

Figure 10. Mean dissolved inorganic nitrogen by season.
The blue line at 0.07 mg/l indicates the DIN level below which nitrogen limitation likely occurs. Winter season includes December (of the previous year), January and February. Spring season includes March-May. Summer season includes July-August (June is a transition month and not included). Fall season includes October and November. Biological nutrient removal of nitrogen at WWTPs is most effective in warmer months, and seasonal changes in phytoplankton populations (blooms in spring and fall) reduce DIN.

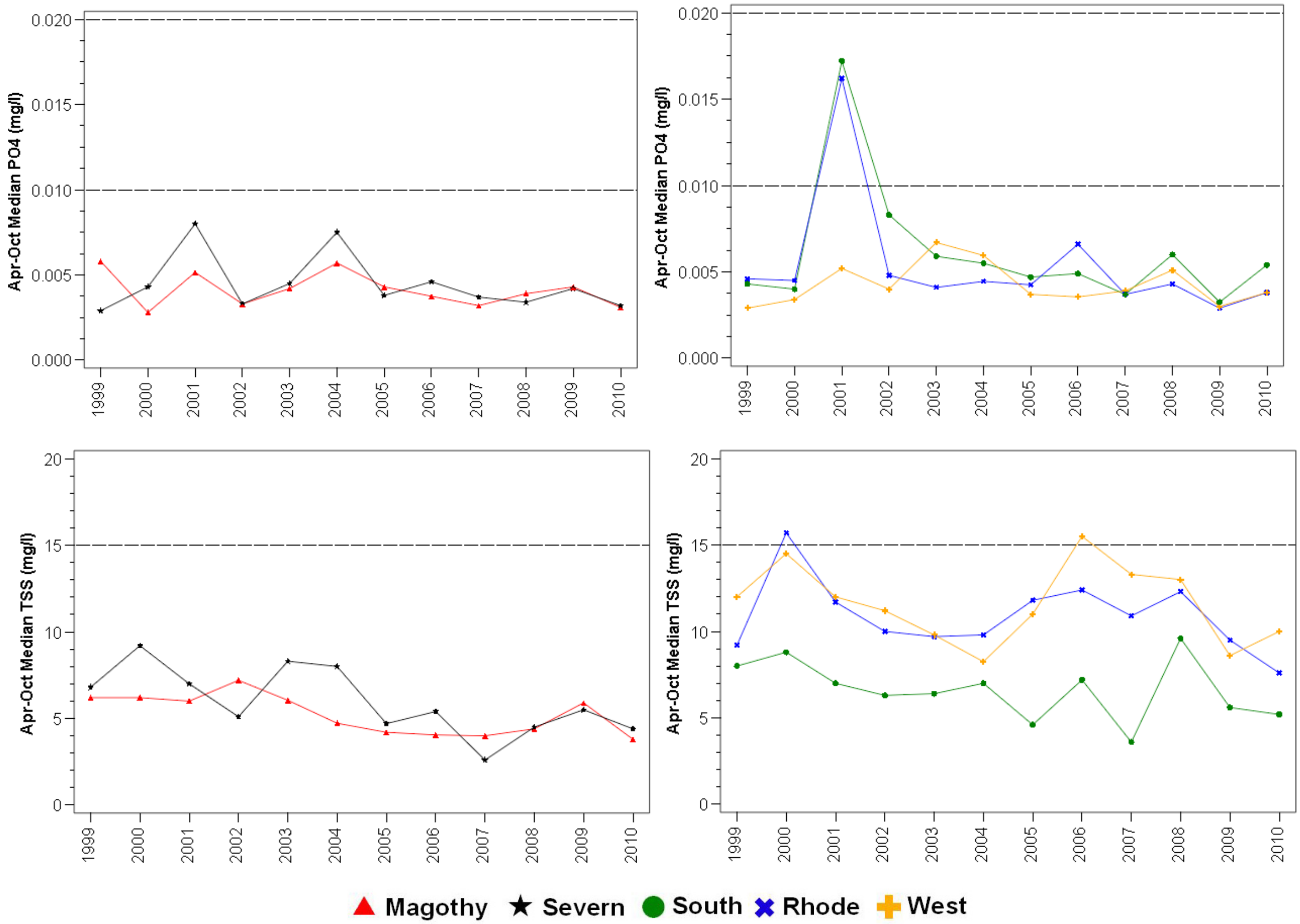

Figure 11. SAV habitat requirement parameters.
SAV growing season (April-October) median values for PO_4 and TSS. Left panels: Magothy and Severn rivers. Right panels: South, Rhode and West rivers. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4 and TSS need to be lower than the threshold. All rivers need to meet the mesohaline thresholds.

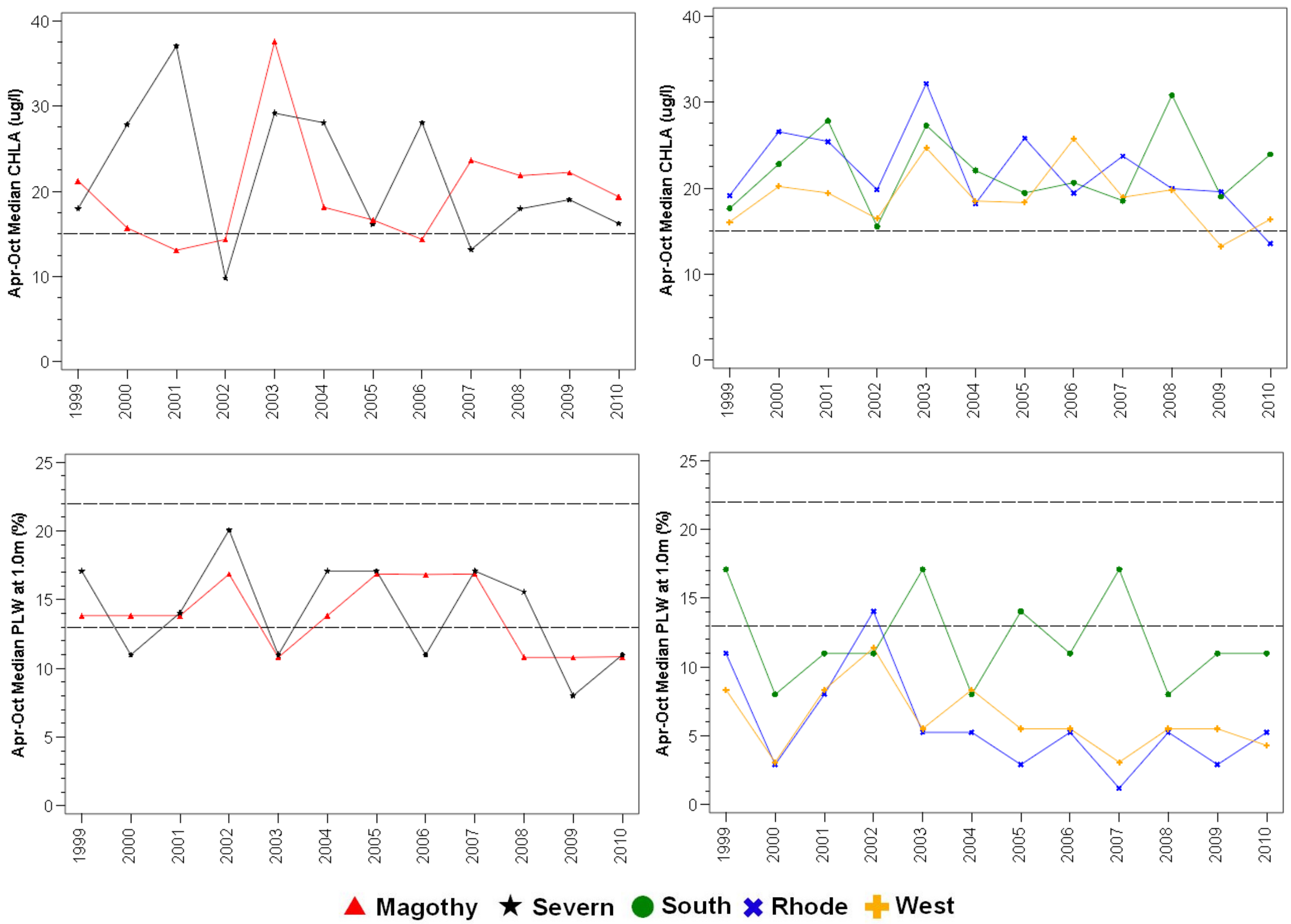

Figure 12. SAV Habitat Requirement parameters (continued).
SAV growing season (April-October) median values for CHLA and PLW. Left panels: Magothy and Severn rivers. Right panels: South, Rhode and West rivers. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of CHLA needs to be lower than the threshold and PLW needs to be above the threshold. All rivers need to meet the mesohaline thresholds.

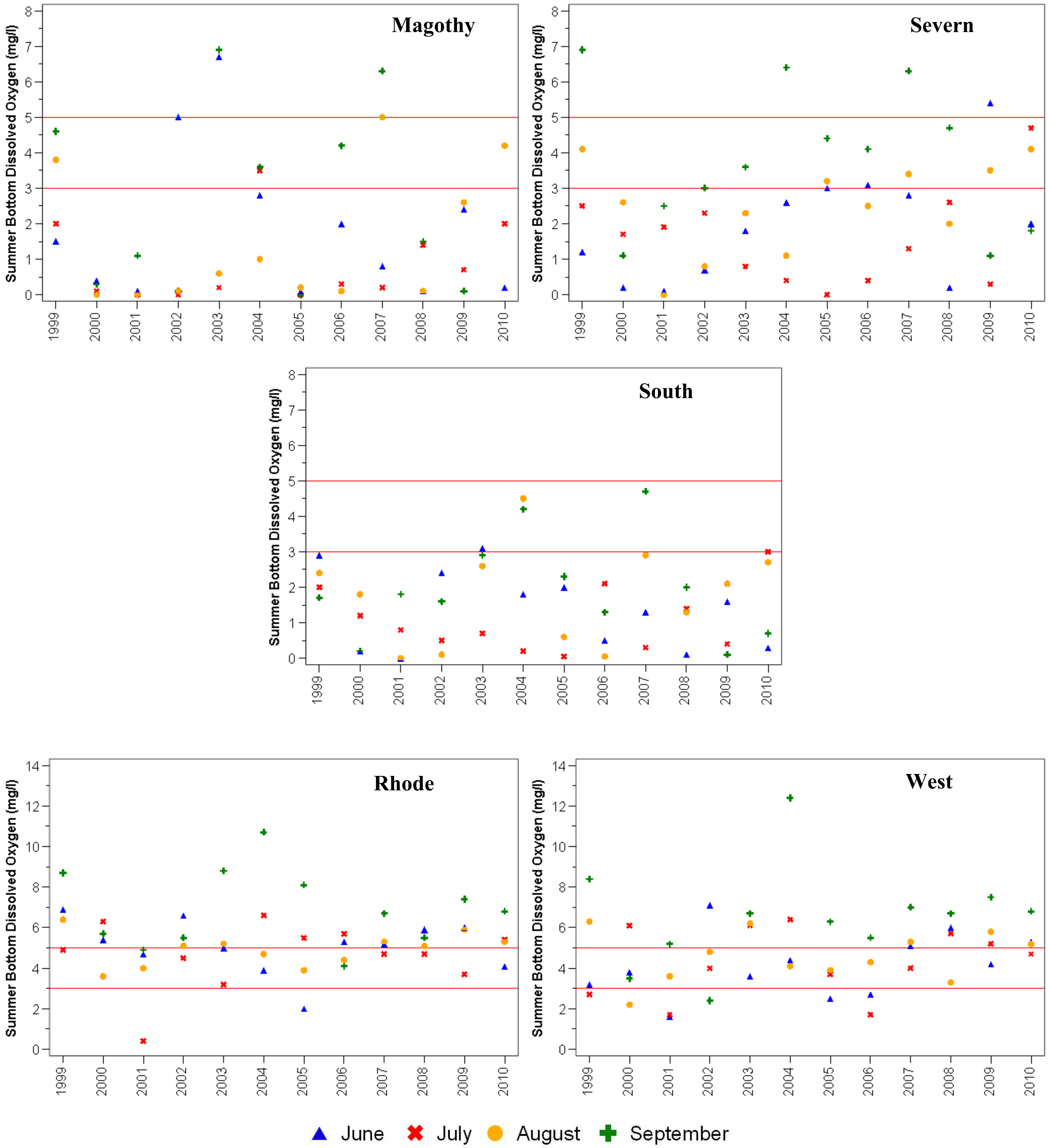

Figure 13. Summer bottom dissolved oxygen levels.
Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

Shallow water

The tidal long-term monitoring program samples at a fixed point that is generally in the center channel and deeper waters of a river. Sampling is usually done once or twice a month. The strength of this type of monitoring is that the repetition of sampling over many years (more than two decades) measures how water quality has changed over time and in response to management actions, land use changes, etc. However, conditions at the long-term monitoring station may not adequately capture water quality conditions in shallow waters, the river as a whole or on short time scales. The shallow water monitoring program is designed to measure conditions in the areas closest to land that are critical habitat areas, especially in the areas with underwater grass beds. Sampling in a river is done for a 3-year period to determine short-term changes in water quality that occur due to weather, such as between a year with very high rainfall and a year with low rainfall. Some shallow water stations have been monitored for longer periods.

The first part of the shallow water monitoring program uses instruments that stay in the water for extended periods (usually April-October) and collect information every 15 minutes; this is called the continuous monitoring program. Instead of the one or two samples a month typical of the long-term monitoring program, the continuous monitoring program can collect more than 2,800 samples a month.[34] This type of monitoring 1) measures water quality changes that occur between night and day, between days and at longer times spans; 2) determines how long water quality problems persist, such as algal blooms or low oxygen water; and 3) measures water quality changes that occur related to weather events such as storms.

The second part of the monitoring program samples all of the shallow waters of a river (or river segment in larger rivers) once a month from April-October; this is the water quality mapping program. Data is collected nearly constantly as a boat moves along the entire shoreline, so changes in water quality can be measured from one part of the river to another. This data captures water quality in very localized areas and can identify places with better or worse water quality than the river overall. This monitoring is also able to capture changes in water quality related to events that occur in only part of the river such as algal blooms or in response to localized nutrient sources.

A full three-year program was completed in the Magothy and Severn Rivers from 2001-2003 and in the South, West, and Rhode Rivers from 2004-2006 (Figure 14, Appendix 3).[35] Sandy Point, located in the Chesapeake Bay along the shoreline of the Lower Western Shore Basin, was also added to the continuous monitoring Program in 2004. Occasionally, special studies and collaborations with other research partners extended the period of study beyond the three-year assessment period.[36] Water quality mapping was also conducted 2004-2007. [37]

In 2010, the South Beach station at Sandy Point (XHF0460) was the only continuous monitoring station operating in the Lower Western Shore Basin. Monitoring continues at the Smithsonian

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[34] Nutrient samples are collected twice a month instead of continuously.
[35] Continuous monitoring began in 2000 in the Magothy River and expanded to the Severn River in 2002. Thus, the data record for the Lower Western Shore Basin spans the years 2000 to the present
[36] An interactive map of all continuous monitoring stations and complete archived data are available at http://mddnr.chesapeakebay.net/newmontech/contmon/archived_results.cfm.
[37] Interpolated maps for all cruises are available on the Maryland Department of Natural Resources "Eyes on the Bay" website http://mddnr.chesapeakebay.net/sim/dataflow_data.cfm

Environmental Research Center (SERC) station in the Rhode River, but in 2007 SERC assumed responsibility for maintenance and data reporting at this site, and the data for recent years are not reported here.

The 2010 continuous monitoring results at Sandy Point South Beach are discussed below, as are results for the other rivers for previous years. Specific examples of the details captured with the shallow water monitoring program are also discussed- the effects of Hurricane Isabel in 2003 and the results of high river flows from the Susquehanna on salinities in the rivers and spatial patterns within rivers.

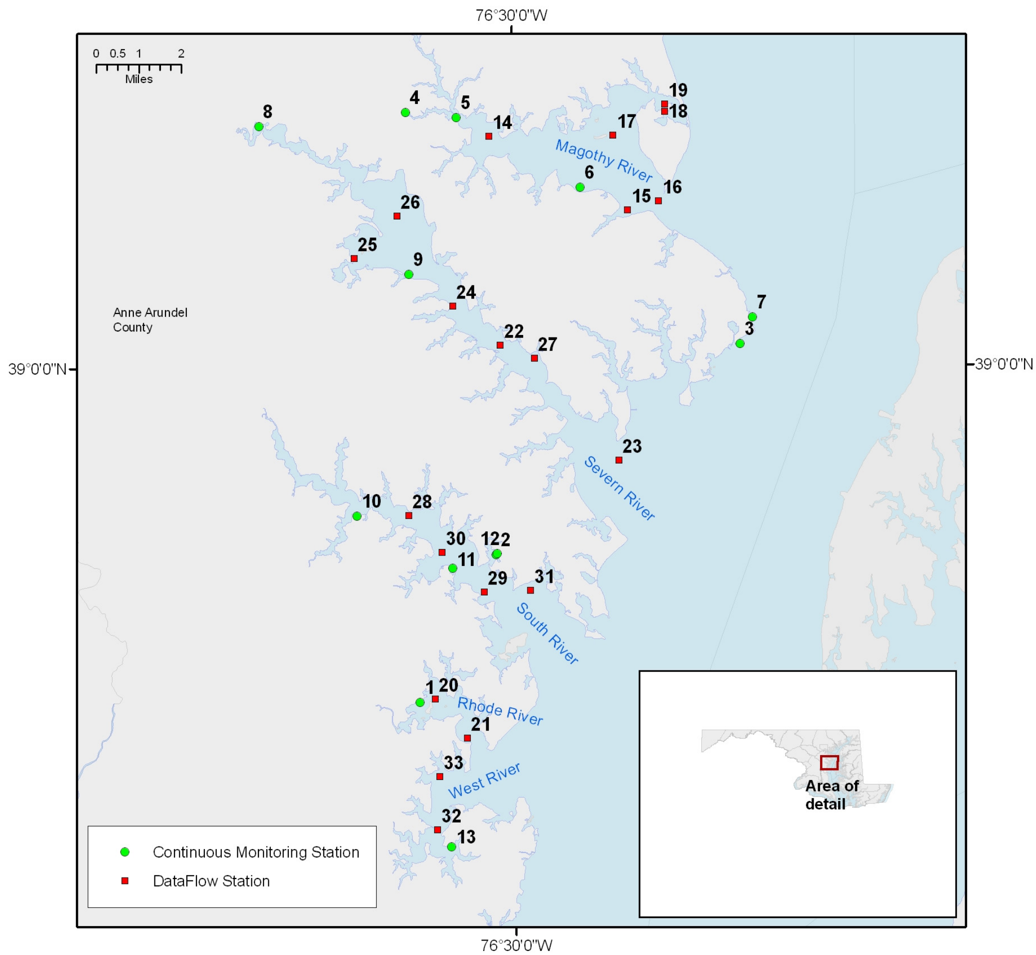

Figure 14. Shallow water calibration stations in the Lower Western Shore Basin. Green circles show the continuous monitoring locations: 1. XGE3275 Rhode River – SERC, 2. ZDM0001 South River - Harness Creek Downstream, 3. XHF0460 Chesapeake Bay - Sandy Point - South Beach, 4. CTT0014 Magothy River - Cattail Creek, 5. CTT0001 Magothy River – Whitehurst, 6. XHF3719 Magothy River – Stonington, 7. XHF0561 Chesapeake Bay Segment 3 - Sandy Point - East Beach, 8. SEV0116 Severn River - Ben Oaks, 9. XHE1973 Severn River - Sherwood Forest, 10. XGE7059 South River - Beards Creek, 11. XGE5984 South River - Cedar Point, 12. ZDM0002 South River - Harness Creek Upstream, 13. XGE0284 West River - Shady Side. Red squares show water quality mapping calibration stations. In the Magothy River these are **14. WT6.1**, 15. XHF3230, 16. XHF3339, 17. XHF4727, 18. XHF5111, 19. XHF5340. In the West/Rhode these are **20. WT8.2,** 21. XGE2488, **32. WT8.3**, 33. XGF1780. In the Severn River these are **22. WT7.1**, 23. XGF8027, 24. XHE1284, 25. XHE2258, 26. XHE3170, 27. XHF0206. In the South River these are **28. WT8.1**, 29. XGE5492, 30. XGE6281, 31. XGF5404. Stations listed in **bold** are also long-term monitoring program stations.

Current Conditions

Mainstem Chesapeake

The 2010 continuous monitoring data at Sandy Point South Beach are shown in Figure 15. Most chlorophyll concentrations for the year were below 30 µg/l. However, chlorophyll values rose above 50 µg/l in late May to early June and peaked above 100 µg/l in mid-August. Chlorophyll concentrations in excess of 50 µg/l are considered indicative of a significant algal bloom while values above 100 µg/l suggest severe algal bloom conditions. During the month of July, when the station recorded the warmest water temperatures, dissolved oxygen values occasionally dropped below 5 mg/l (a condition which can be harmful to living resources) and pH briefly dropped below 7. Although most turbidity values at South Beach were below 25 NTU in 2010, numerous brief spikes above 50 NTU occurred throughout the year. A spike in turbidity above 100 NTU occurred in August and coincided with elevated chlorophyll levels. Turbidity spikes near 100 NTU also occurred in late June and late September. The late September turbidity spike was likely the result of high winds and heavy rain from Tropical Storm Nicole which arrived in the Chesapeake Bay region on September 30, 2010. Salinity and temperature values at Sandy Point South Beach also dropped in late September due to Tropical Storm Nicole.

Temporal and Spatial conditions

Water and habitat quality in the shallow water was evaluated in two ways. The first was a temporal assessment. High temporal frequency data from the continuous monitoring program were used to determine how often water quality met conditions needed for healthy habitats. Percent failures are defined as the percent of values in each year that did not meet the water quality thresholds (see Appendix 4 for methods). Data for the years 2000-2010 were used. Chlorophyll and turbidity measurements collected during the SAV growing season (April through October) and summer dissolved oxygen values (June through September) were included in the analysis. The percent failures for all stations are shown in Appendix 8.

The second method was a spatial assessment. The nutrient data collected at continuous monitoring and water quality mapping calibration stations for April-October were compared to the SAV habitat requirements (Appendix 8). Water quality and habitat conditions were also compared between the shallow water stations and the long-term station.

The tributaries of the Lower Western Shore showed similar water quality conditions based on the results of the percent failure analysis. In general, dissolved oxygen levels dropped below the 3.2 mg/l threshold less than 10% of the time throughout the basin. The most upstream reaches of some tributaries (Cattail Creek in the Magothy River, Ben Oaks in the Severn River, and the upstream station in Harness Creek) showed greater percent failures of the 3.2 mg/l dissolved oxygen threshold, at 20% or more. The stations at Sandy Point, located in the more open waters of the Chesapeake Bay, had the least percent failures for dissolved oxygen, with generally less than 1% of measurements below 3.2 mg/l during 2004-2010.

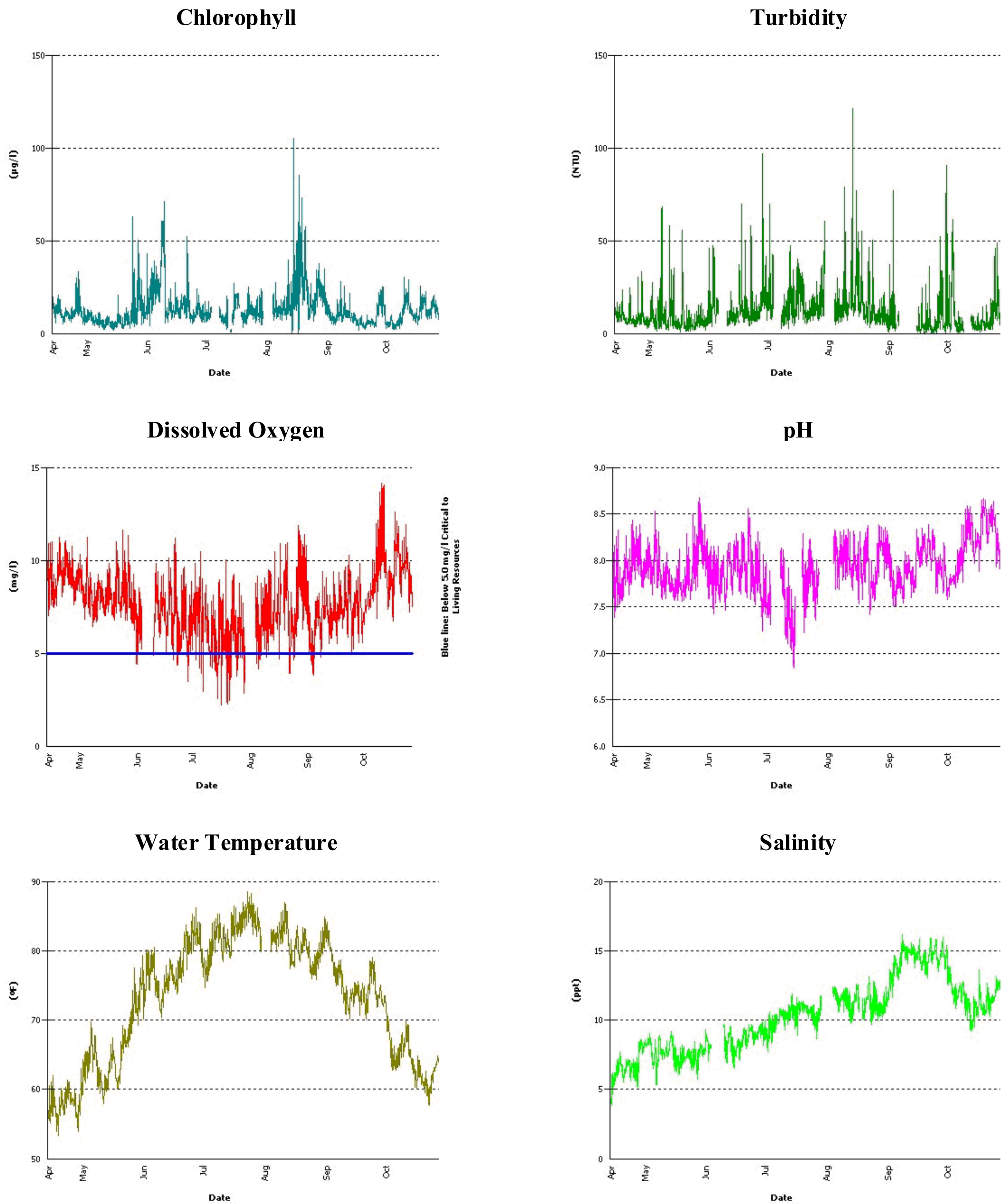

Figure 15. Continuous monitoring results at Sandy Point (South Beach) in 2010.

For the 15 µg/l chlorophyll threshold, percent failures at Sandy Point were generally less than 40%, while failures at all tributary stations were between 40%-85% during most years. The highest failure rates for chlorophyll were observed in the Magothy River (65%-85% failure) and at Ben Oaks in the Severn River (84%-93% failure). In contrast to dissolved oxygen and chlorophyll, which showed better conditions at Sandy Point, turbidity exceedences were frequent at this station in the Chesapeake Bay, with percent failures of generally 50-85% for the 7 NTU turbidity threshold. West and Rhode Rivers, Ben Oaks in the Severn River, and Cattail Creek in the Magothy River all had more than 70% of measurements exceed the 7 NTU turbidity threshold. Beards Creek in the South River, and Sherwood Forest in the Severn River had the fewest percent failures for turbidity at less than 25%.

The percent failure analysis determines how often dissolved oxygen levels were below healthy levels, but not how long at any one time dissolved oxygen levels were dangerously low. This is important because most benthic animals and fish can survive in low dissolved oxygen for short periods but not extended periods. A special study of the continuous monitoring data from Maryland rivers, including the data for the Magothy River (Stonington data for 2001-2003 and Whitehurst data for 2002-2003), found that periods of dissolved oxygen levels below 3.2 mg/l at different locations lasted from as little as 15 minutes to as long as 2.5 days.[38] The longest continuous period of extremely low dissolved oxygen at Stonington was 7 hours and at Whitehurst was 9 hours. The percentage of time in a sample year with extremely low dissolved oxygen levels ranged from 0.4% (in 2001 at Stonington) to 2% (in 2002 at Whitehurst).
When compared to the SAV habitat requirements, in 2003 the shallow waters of the Magothy River and Severn River met the TSS, PO_4 and DIN requirements but failed the CHLA and Secchi depth requirements. In the Severn River, DIN levels at the Ben Oaks station were significantly higher than at Sherwood Forest and the long-term station, and TSS levels were significantly higher than about half of the other shallow water stations.

Magothy River shallow water was similar among all stations including the long-term station for all parameters.[39] In the Severn River, CHLA levels were similar among the stations with the exception that levels at the long-term station were significantly higher than at the station in the mouth of the river. TSS levels were significantly higher at the Ben Oaks Station than at the Sherwood Forest and in Round Bay (XHE2258). DIN and PO_4 levels were significantly higher at Ben Oaks than Sherwood Forest.[40]

In 2004-2006, shallow waters of the South River met the TSS and PO_4 habitat requirements, but failed to meet the CHLA and Secchi depth requirements. Upper South River stations (from Beards Creek to Cedar Point, including the long-term station) generally met the DIN habitat requirement while lower river stations generally failed to meet the requirement. Shallow waters of the Rhode and West rivers also met the PO_4 habitat requirement and failed to meet the Secchi depth requirement. Only one station in lower Rhode River (XGE2488) met the CHLA requirement. Rhode River stations generally met the DIN requirement and the West River stations generally failed to meet this requirement.

[38] Boynton et al (2011) available online at http://www.gonzo.cbl.umces.edu/documents/water_quality/Level1Report28.pdf
[39] Because only the 2003 data was included, smaller sample sizes may be reducing the power of the statistical tests for difference between stations.
[40] DIN levels at Ben Oaks were also significantly higher than at the long-term station. TN and TP levels at Ben Oaks were significantly higher than all but the long-term station and XHF0206.

In the South River, DIN levels at the Beards Creek were significantly lower and PO_4 levels were significantly higher than at the mouth of the river but the other stations were similar to one another.[41] TSS levels in the Rhode River were significantly higher and Secchi depths were significantly lower at the SERC station than in the rest of the river.[42] In the West River, only Secchi depth was different between the two stations, with water clarity at Shady Side being lower than at the long-term station.

Water quality patterns

Figure 16 shows the water quality mapping survey results for the South River in September 2005 and July 2006. These results illustrate a recurring pattern in dissolved oxygen distribution in the river. On both of these dates, higher values of dissolved oxygen occurred along the northern shoreline, and values below 5 mg/l were located in some of the upper branches of the river.

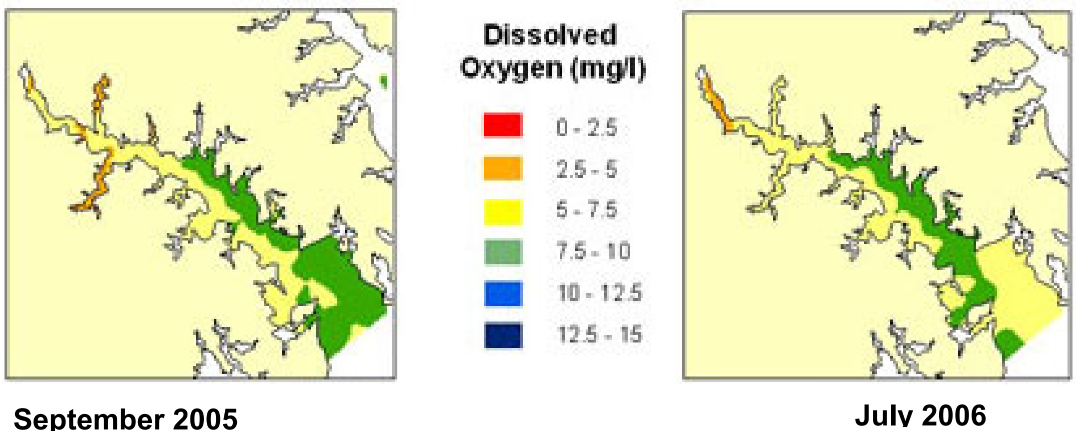

Figure 16. Water quality mapping survey results for dissolved oxygen in the South River, September 2005 and July 2006.

For the West and Rhode Rivers, water quality mapping results are shown for October 2004 (Figure 17). During the week of the October mapping cruise, a nearly full moon caused astronomically higher tides in the Chesapeake Bay. At the same time, a large storm in the western Atlantic prevented water from draining out of the Bay. This combination of events drove tidal levels in the Chesapeake Bay one to two feet above normal and caused localized flooding of low lying areas. The water temperature data map for October 2004 shows the effects of the higher tide cycles with an influx of warmer Bay waters at the mouth of the Rhode and West rivers.

[41] TP levels in the South River were significantly higher at Beards Creek than at the middle and lower river and stations.
[42] TN levels at SERC were significantly higher than at the stations in the outer river (XGE2488 and XGF1780). TP levels at SERC were higher than the rest of the stations.

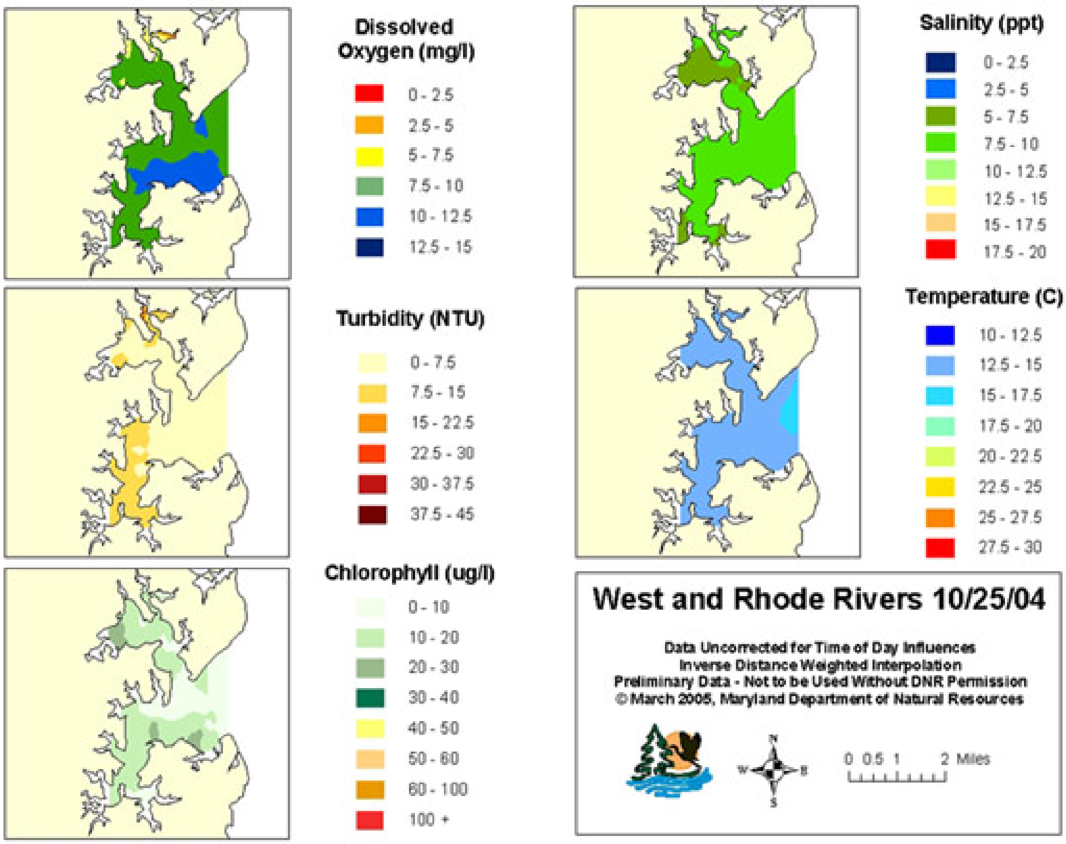

Figure 17. Water quality mapping survey results for the West and Rhode Rivers, October 2004.

Water quality mapping data reveals an interesting pattern in salinity for the Severn and Magothy Rivers in 2001 and 2002. During springtime high flows, greater volumes of freshwater are released from the Conowingo Dam on the Susquehanna River. Approximately ten days after these higher freshwater releases, freshwater is observed infiltrating into the mouths of the Magothy and Severn (Figure 18), resulting in a horizontal salinity inversion (higher salinities upstream than downstream). This phenomenon could harm living resources, such as yellow perch, by constricting their habitat ranges upriver, making them more susceptible to mortality.

Hurricane Isabel

Continuous monitors are especially well suited to record the impact of weather events on water quality. Hurricane Isabel was a major storm that passed directly over the Chesapeake Bay on September 18, 2003. This storm brought significant rain to the region, but even more damaging was the large tidal surge associated with the storm. As winds piled water up along the western shore of the Chesapeake Bay, tide heights rose as much as 5 feet above normal. The impacts of this tidal surge were observed at the Stonington continuous monitoring station in the Magothy River where a slight increase in salinity was observed and turbidity levels increased substantially (Figure 19). In the days following Hurricane Isabel (September 26-27, 2003), a bloom of algae occurred in the Magothy River (Figure 20). As the bloom died and began to decompose, dissolved oxygen levels dropped below 5 mg/l on September 30, 2003.

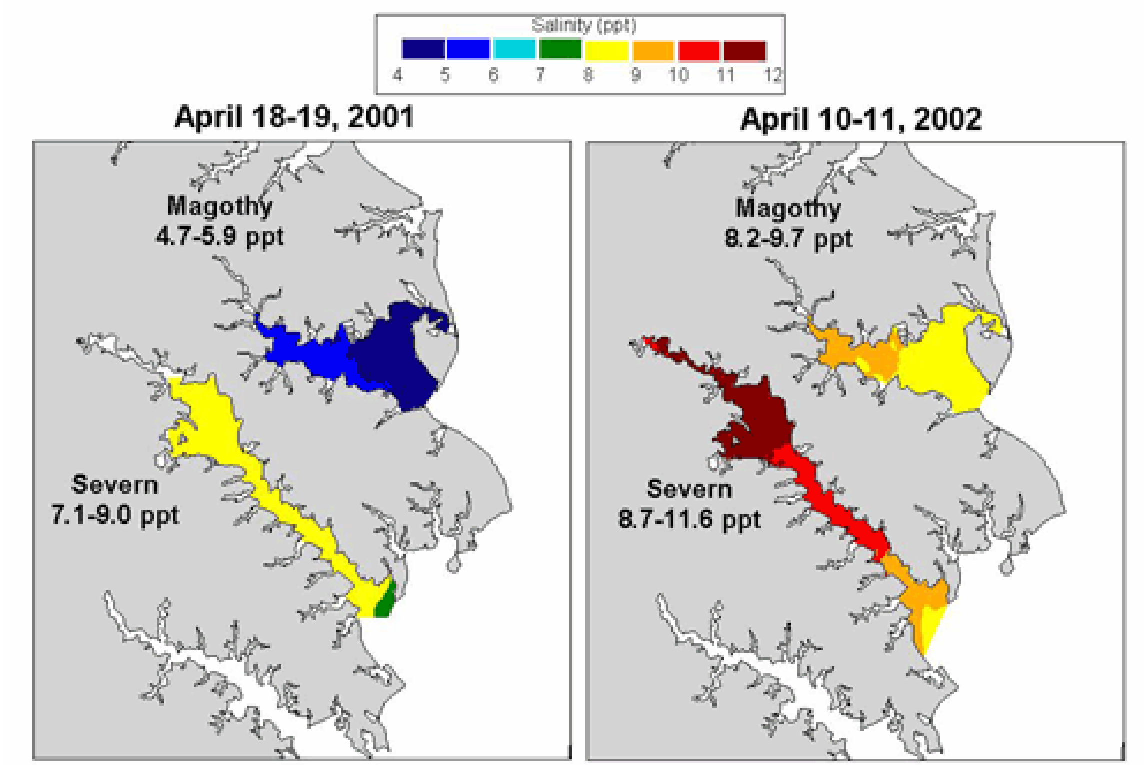

Figure 18. Water quality mapping survey results for salinity in the Severn and Magothy Rivers, April 2001 and April 2002.

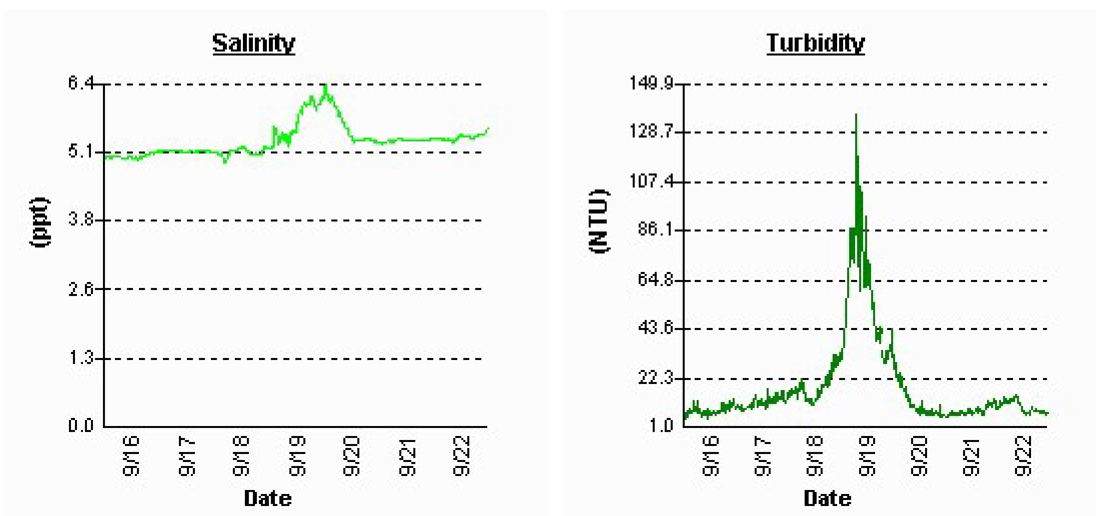

Figure 19. Salinity and turbidity data during 16 - 22 September 2003 from the continuous monitoring station at Stonington on the Magothy River.

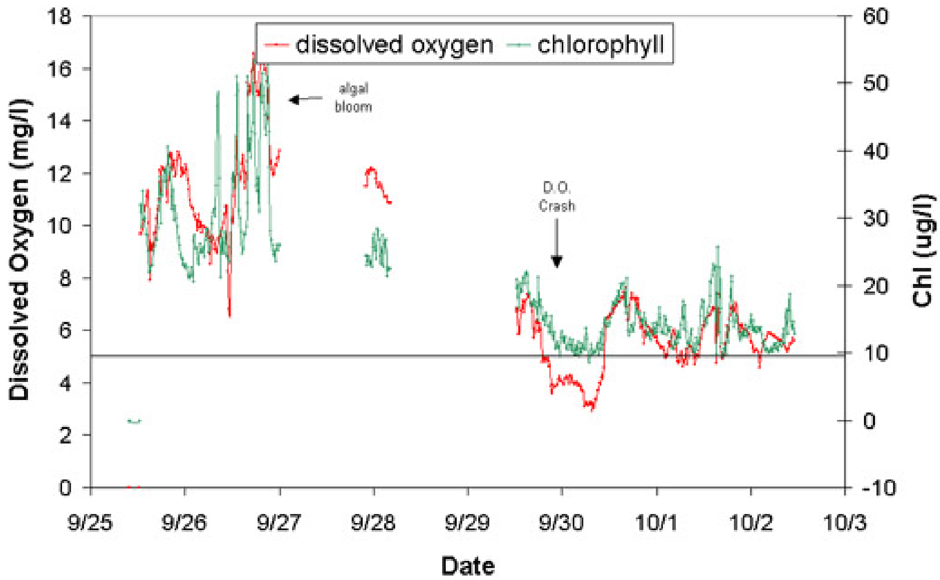

Figure 20. Dissolved oxygen and chlorophyll data during 25 September 2003 to 3 October 2003 from the continuous monitoring station at Whitehurst on the Magothy River.

Special Projects- Impact of Oyster Bar on Water Quality

The continuous monitors in Harness Creek in the South River were installed as part of a special project to investigate the effectiveness of native oysters in improving water quality, specifically to support bay grass restoration, growth, and survival. In 2003, an oyster reef was constructed across the mouth of a small cove in Harness Creek and seeded with oyster spat, as well as one- and two-year old oysters. Oysters were periodically added to the reef to increase the filtering capacity of the oyster bar, and continuous monitoring was initiated at stations upstream and downstream of the oyster bar to track improvements in water quality as a direct result of the oysters. The percent failure results for Harness Creek indicate that dissolved oxygen measurements dropped below the 3.2 mg/l threshold more often during 2007 than in the years 2006 and 2008. The Chesapeake Bay region experienced drought conditions during the summer of 2007, and it is likely that the hot, dry weather contributed to the increased number of low dissolved oxygen values recorded in Harness Creek during this year. From the percent failure analysis, it also appears that the upstream station at Harness Creek failed the dissolved oxygen threshold more often than the downstream station. It is important to note, however, that the percent failure analysis was not intended to analyze in detail the differences in water quality between these stations. A more robust data analysis, as reported in "Coupling Oyster and SAV Restoration in South River, Maryland"[43] suggested that the oyster bar was having a localized impact on water quality in Harness Creek and that improvements in water quality were occurring as water flowed across the oyster bar.

[43]Report available online at www.dnr.state.md.us/bay/sav/restoration/coupling_oyster_future_sav_restoration_report_southriver.pdf

Health of Key Plants and Animals

Phytoplankton

Phytoplankton (generally algae) are the primary producers in the Chesapeake Bay and rivers and the base of the food chain. Routine samples collected in the long-term tidal and shallow water monitoring programs estimate the abundance of algae but can not determine the health of the population overall. As part of a supplemental program, the overall phytoplankton community was sampled at the long-term tidal water quality station in the Magothy and South Rivers in spring and summer. The phytoplankton index of biotic integrity (PIBI) assesses the health of the community.[44] A PIBI score of greater than 3 is considered meeting the goal for phytoplankton community health criteria. Spring PIBI scores in the Magothy met the goals in three of the four years, but Summer PIBI scores failed in all four years (Figure 21).[45] Spring and Summer PIBI scores failed in all years in the South River. The data record is not long enough to test for trends.

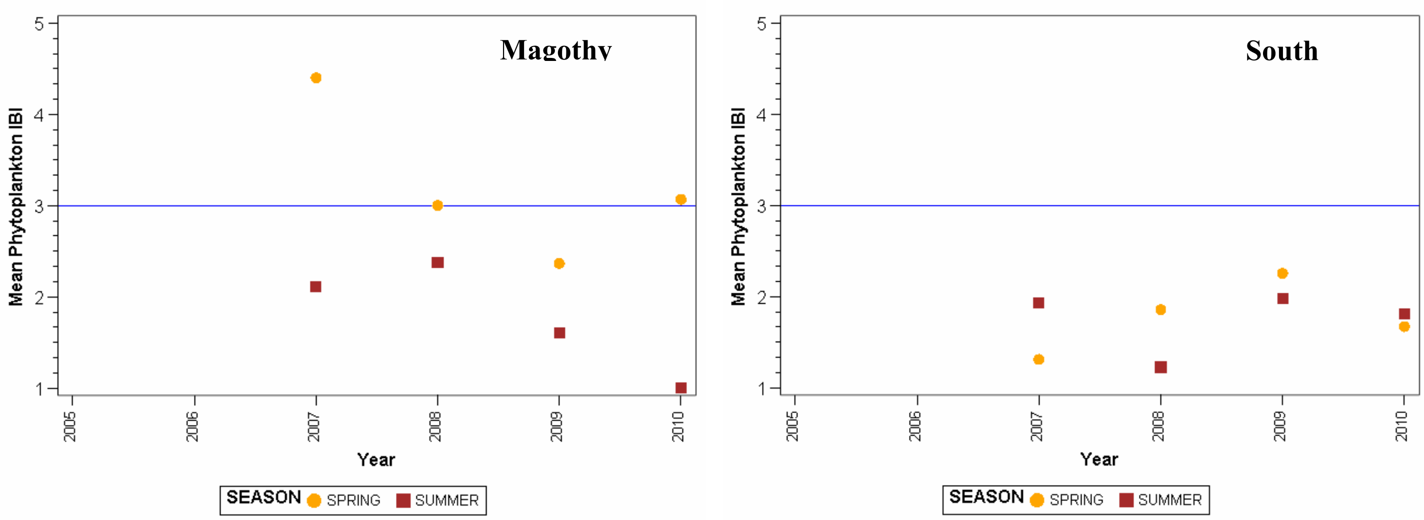

Figure 21. Spring and summer Phytoplankton Index of Biotic Integrity (PIBI) scores 2007-2010.

Harmful Algal Blooms (HABs)

High algal density (algal blooms) can degrade habitat quality. Blooms of certain species of phytoplankton (harmful algae) can also degrade habitat quality. Routine samples collected in the long-term tidal and shallow water monitoring programs can not distinguish between good and harmful algae. Additional samples are taken at some locations to determine what algal species are present and in what densities. When a bloom occurs, samples are taken to test for the presence and levels of toxins, which can be released by some types of harmful algae. Fortunately, of the more than 700 species of algae in Chesapeake Bay, less than 2% of them are believed to have the ability to produce toxic substances.[46]

Blue-green algae are generally smaller cells and not as nutritious and edible to small animals (zooplankton). Blooms of blue-green algae look like blue-green paint floating at or near the

[44] Methods for calculation of the PIBI are available at www.chesapeakebay.net/.../indicator_survey_phyto_ibi_2011_final.docx

[45] P-IBI scores calculated by J. Johnson, Interstate Commission on the Potomac River Basin/Chesapeake Bay Program.

[46] Information on Harmful Algal Blooms is available at http://mddnr.chesapeakebay.net/eyesonthebay/habs.cfm

water surface (Figure 32). Blue-green algae can only live in low salinity waters. Some species of blue-green algae (*Microcystis* and *Anabaena*) can produce a toxin that is released into the water. Contact with or ingestion of water containing high toxin levels can cause human health impacts (skin irritation, gastrointestinal discomfort), and can be harmful or even fatal to livestock and pets.

Blooms of some species of dinoflagellates are known as 'mahogany tides' because the color of the algae and the density of algae in the bloom make the water appear brown or reddish-brown (Figure 32). These conditions are most often caused by blooms of *Prorocentrum minimum*. While *Prorocentrum* frequently blooms in the spring, blooms have been observed in Maryland waters in all seasons. These algae do not produce a toxin, but the magnitude of the bloom can harm fish and shellfish by replacing more nutritious algae, depleting oxygen in the water column or clogging gills. The darkened waters can also reduce the light reaching underwater grasses.

Other harmful algal species can lead to fish kills. *Karlodinium venificum* can release a toxin that harms fish, and densities above 20,000 cells/milliliter can be acutely toxic to fish. Extremely low dissolved oxygen is often the result of the abrupt die off of a bloom, when the process of decomposing the large amount of plant material uses up the oxygen in the water. The combination of the toxin and low dissolved oxygen can lead to fish kills.

Figure 22. Harmful algal blooms.
Left panel: Blue-green algae bloom. Right panel: 'Mahogany tide' bloom.

HABs are a recurring issue in the Lower Western Shore rivers, especially the Magothy and Severn rivers. Portions of these rivers with low salinities are suitable habitat for blue-green algae.

Underwater grasses

Water quality determines the distribution and abundance of underwater grasses (submerged aquatic vegetation, SAV). For this reason, SAV communities are good barometers of the health of the tidal rivers and bays. SAV is also a critical nursery habitat for many bay animals. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region. SAV distribution is determined through the compilation of aerial photography directed by the Virginia Institute of Marine Science (VIMS).[47]

Magothy River
Although the Magothy River showed an increasing trend in SAV coverage until 2005, when 308 acres were identified, it's been steadily declining since then (Figure 23). With a restoration goal of 579 acres, 2008 fell far short with only 15% of that goal, or 89.65 acres. SAV coverage dropped again in 2009 to 12.11 acres, and in 2010, there was only 1.75 acres of SAV identified through the VIMS aerial survey (Figure 24). That represents only 0.3% of the restoration goal.

Severn River
The Severn River was likewise doing well when in 2006 it reached 411 acres of SAV coverage, or 90% of its 455 acre restoration goal. In 2008, SAV coverage was down to 311.24 acres and in 2009 it dropped another 100 acres to total 211.01. Fortunately, the decline wasn't as great between 2009 and 2010, but SAV coverage still declined to 174.78 acres in 2010. That amount of SAV represents 38% of the restoration goal for the Severn River.

South River
The South River showed an increasing trend in SAV coverage, beginning in 1994 and ending in 1998, when SAV coverage was 54 acres. In 2004, SAV coverage increased dramatically to 46 acres, and then declined to 10 acres in 2005. Since 2005, the South River has lost all of its SAV, meeting 0% of its 478 acre SAV restoration goal.

Rhode River
The VIMS aerial survey has not detected SAV in the Rhode River since 1978, although ground-truthing has indicated that small patches appear occasionally. The Rhode River has an SAV restoration goal of 60 acres.

West River
The West River has had very little SAV mapped since 1984. There were approximately 10 acres in 1994 and 1998 and 23 acres in 2003, well below the restoration goal of 238 acres. No SAV has been identified in West River by aerial surveys since 2004.

[47] Reports detailing methodology and annual SAV coverage are available at www.vims.edu/bio/sav . Details on species of SAV discussed in this report can be found at www.dnr.maryland.gov/bay/sav/key

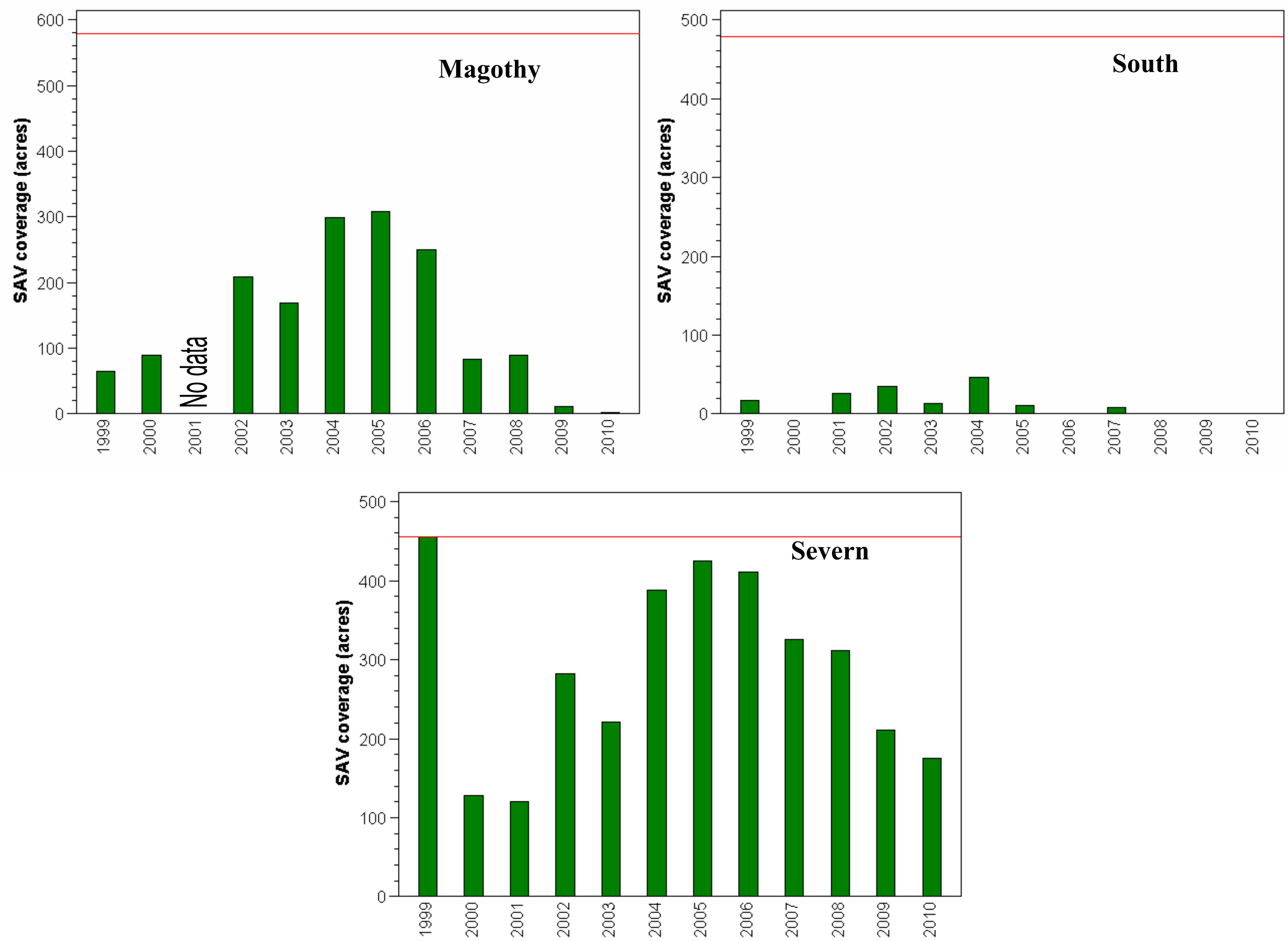

Figure 23. SAV coverages in the Magothy, South and Severn Rivers 1999-2010.
SAV data provided by the Virginia Institute of Marine Science. Red line shows the restoration goal for each river.

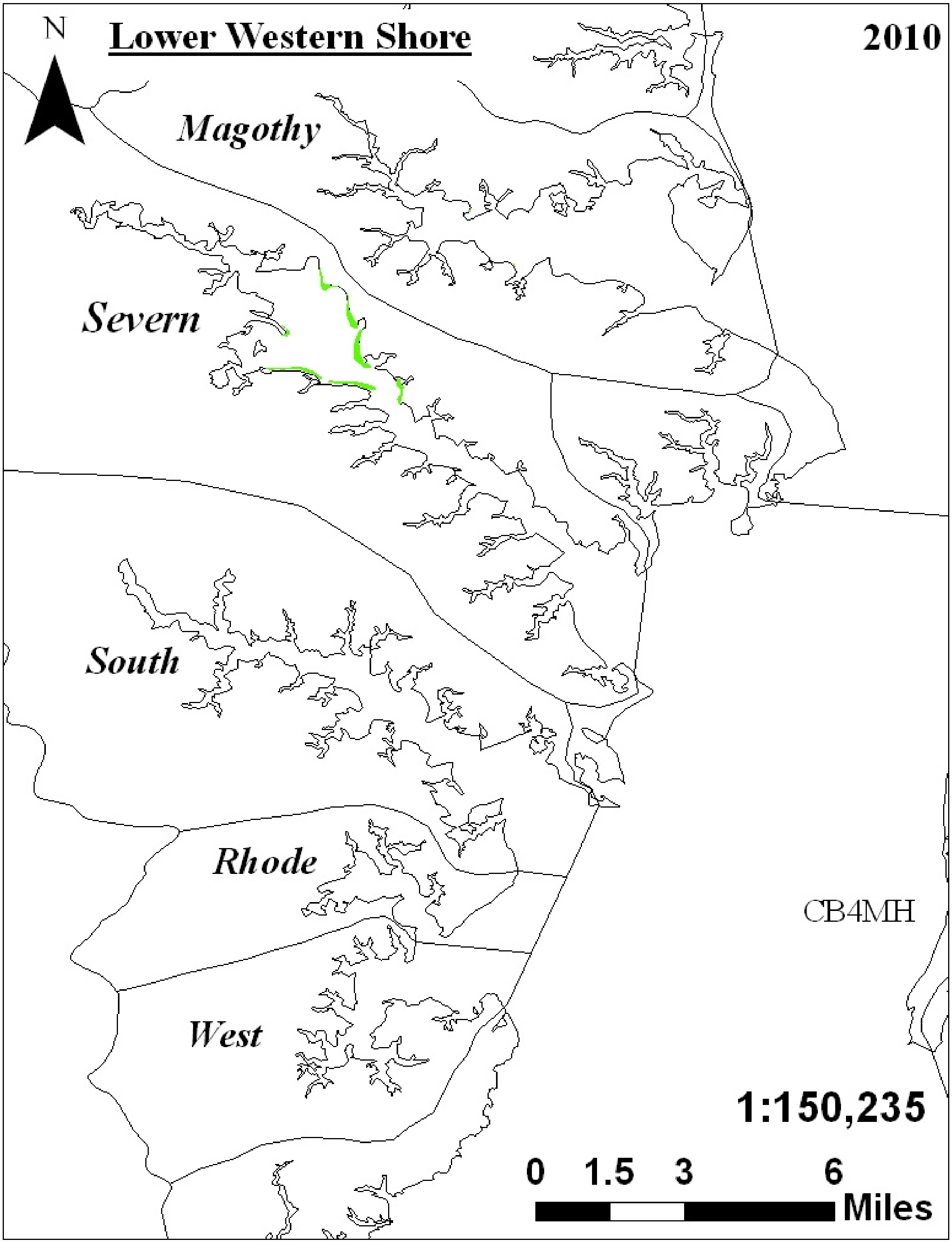

Figure 24. SAV beds (in green) in the Lower Western Shore Rivers in 2010.
SAV data provided by the Virginia Institute of Marine Science.

Benthic animals

Benthic animals are the animals that live in or on the bottom of the bay. To determine the health of benthic communities, samples are collected in the summer at one long-term benthic monitoring station in the Severn River. This station has been monitored since 1995. Starting in 1994, samples were also collected from all of the rivers and mainstem Bay each year from randomly selected locations. Within the smaller western shore rivers (excludes the Patuxent and Potomac), there are not a fixed number of samples each year in any particular river and each river is not sampled in every year. Larger rivers end up with more samples collected over time. The benthic index of biotic integrity (BIBI) assesses the health of the benthic community.[48] A BIBI score of greater than 3 is considered meeting the goal for benthic community health.

In 2008-2010, the benthic community in the Severn at the long-term station was healthy but no trend was detected. During this time period, 22 random samples were collected in the Lower Western Shore rivers (Figure 25). The Magothy and the West Rivers were both sampled in two locations and benthic community health was degraded or severely degraded at all of these locations. Rhode River was sampled twice, with one site meeting goals and one degraded site. In the Severn and South river, benthic community health was almost entirely degraded or severely degraded. The results indicated that about 70-100% of the total benthic habitat was degraded in 2008-2010.[49]

In the western shore tributaries as a group, overall benthic community health was worse in 2005-2010 than in previous years.[50] Benthic community health in the rivers is degraded due to the combined effects of low dissolved oxygen, high nutrient loadings and sediment contamination with toxic chemicals (in some locations).[51] Fewer organisms (reduced abundance) and fewer species have been found and indicate very poor habitat quality due to low dissolved oxygen. Worsening low dissolved oxygen conditions may have resulted from higher spring flows in recent years compared to earlier years. Higher flows cause higher nutrient loadings and contribute to earlier and more extensive areas of low dissolved oxygen conditions.

[48] Methods for calculation of the BIBI are available at http://www.baybenthos.versar.com/DsgnMeth/Analysis.htm#BIBI.

[49] Annual reports for 2008, 2009 and 2010 are available online at http://www.baybenthos.versar.com/referenc.htm.

[50] See Annual reports, section 4.

[51] See Annual reports, section 4.

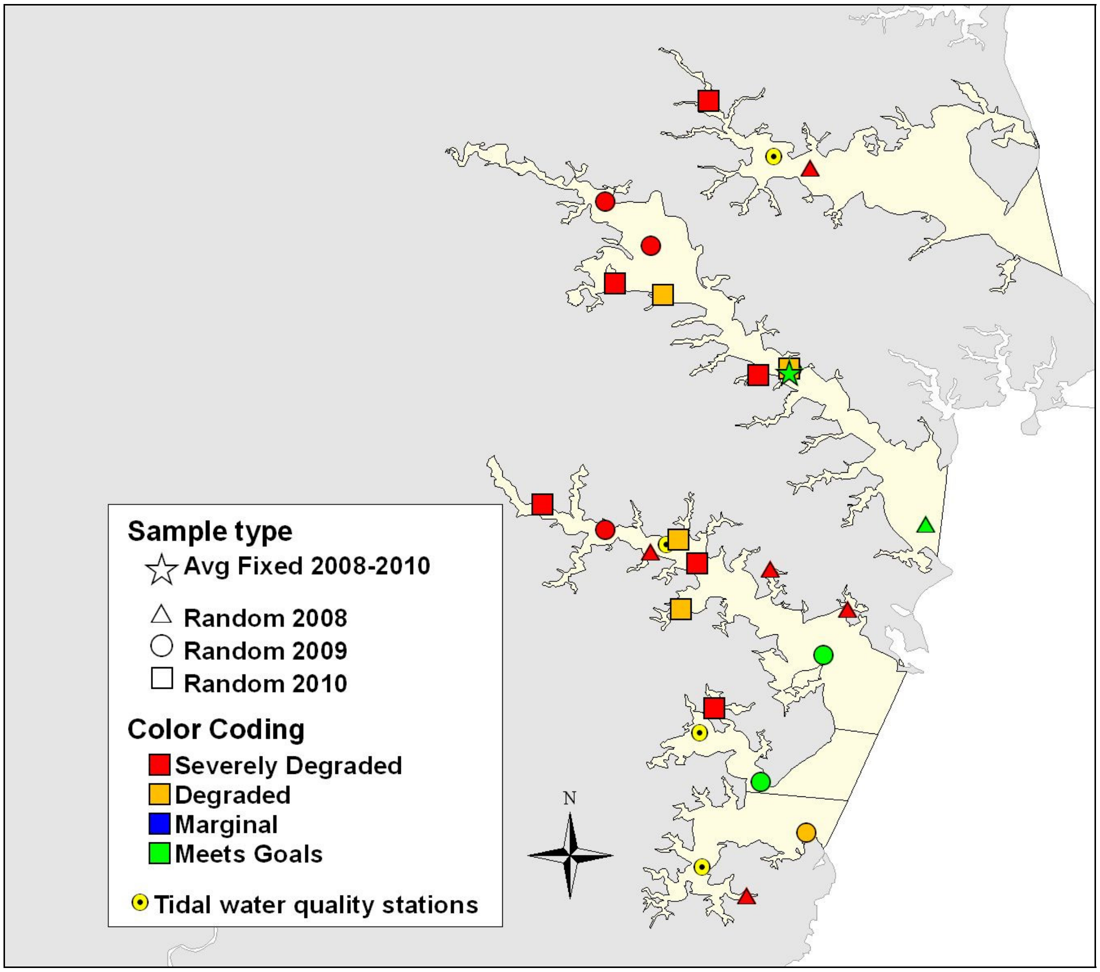

Figure 25. Benthic Index of Biotic Integrity results for 2008-2010.
Random samples were collected in 22 locations in these years. Yellow circles show locations of long-term tidal water quality monitoring stations. A BIBI score of 3 or greater Meets Goals. BIBI scores of 2.7-2.9 are Marginal, 2.1-2.6 are Degraded and less than 2.1 are Severely Degraded.

Summary of Water and Habitat Quality Conditions

Information on current water and habitat quality and the changes through time is needed to assess the health of a river. Many types of information are needed to most completely understand the current conditions. In some instances the assessment is straight forward and all of the information indicates both good water quality and healthy habitats. Most often, some aspects of the overall picture indicate good conditions and other aspects indicate poor conditions. The summary presented here is intended to best represent an overall condition. This is a simplified version and can not capture all the detail presented in the previous sections of this report. Informing the public about the overall health of a river is often best done with a summary of all of the data. Management decisions can benefit from both the summarized and the detailed information.

The Lower Western Shore basin can be divided into two regions. The upper region includes the areas that drain to the Magothy, Severn and South rivers. The lower region includes the areas that drain to the Rhode and West Rivers and directly to the mainstem Bay. Differences in land use, percent impervious surfaces and human population density contribute to variable water and habitat quality. These differences also lead to different management needs and strategies for each region.

Upper Region

Two of the three sub-watersheds in the upper region are medium priority for restoration efforts through Maryland's Trust Fund Program. Stream health is poor in Magothy River and South River sub-watersheds and fair in the Severn River sub-watershed. Human population density is moderate to high. Urban land uses covers 54% of this region, and urban land use has increased by 11% since 2000. Impervious surfaces cover 13% of this region.

Septic, urban and point sources are the most important contributors of nitrogen and phosphorus. The largest source of sediments to the region is urban runoff. There is no water quality monitoring in non-tidal streams of the upper region.

Magothy River
Tidal water monitoring in the Magothy River found improvements in water quality due to reductions in nitrogen (N), phosphorus (P) and sediments (S). N levels were low enough for nitrogen limitation of algal growth in the summer and fall. Habitat requirements for submerged aquatic vegetation (SAV) were met for P and S, but habitat quality was impaired due to worsening algal densities and poor water clarity. Bottom dissolved oxygen levels were very poor and habitat quality for benthos was degraded.

Shallow water monitoring in three locations indicated turbidity failed to meet good habitat quality requirements at least 30% and by more than 90% of the time in Cattail Creek. Chlorophyll levels meet criteria more than 60% of the time. Summer dissolved oxygen levels in the shallow waters were less than 3 mg/l more than 90% of the time in Cattail Creek, but passed the 5 mg/l criteria more than 70% of the time Whitehurst and at least 90% of the time at Stonington.

SAV populations fluctuated over the years, but have declined dramatically since 2005. In 2010, only 1.75 acres of underwater grass beds were measured, 0.3% of the restoration goal. Monitoring of benthic populations was limited in the Magothy but found impaired populations. Phytoplankton populations were also impaired.

Severn River

Tidal water monitoring in the Severn River found improvements in water quality due to reductions in S and maybe P. N levels were low enough for nitrogen limitation of algal growth in the summer and fall. Habitat requirements for SAV were met for P and S, but habitat quality was impaired due to poor water clarity and algal densities. Bottom dissolved oxygen levels were very poor and habitat quality for benthos was degraded.

Shallow water monitoring at Ben Oaks indicated failure of dissolve oxygen, chlorophyll and turbidity criteria 50-95% of the time. Water and habitat quality was much better at Sherwood Forest, passing all criteria more than 80% of the time. Summer dissolved oxygen levels in the shallow waters at Ben Oaks were less than 3 mg/l 20% of the time.

SAV populations have declined since 2006 when 90% of the restoration goal was met. In 2010, only 175 acres of underwater grass beds were measured, 38% of the restoration goal. Monitoring of benthic populations in the Severn River includes a long-term monitoring location where populations were currently healthy. Benthic populations at other locations were impaired with the exception of one site at the mouth of the river that was healthy.

South River

Tidal water monitoring in the South River found worsening conditions due to increasing N but improvements in P and S. N levels were low enough for nitrogen limitation of algal growth in the summer and fall. Habitat requirements for SAV were met for P and S, but habitat quality was impaired due to poor and worsening water clarity and high algal densities. Bottom dissolved oxygen levels were very poor and habitat quality for benthos was degraded.

Shallow water monitoring in Beards Creek indicated oxygen, chlorophyll and turbidity met criteria more than 75% of the time. Water and habitat quality in Harness Creek was worse upstream of the oyster bar than downstream, but at both locations dissolved oxygen and chlorophyll failed to meet criteria 25-60% of the time and failed to meet turbidity criteria 50-85% of the time. Upstream dissolved oxygen levels were less than 3 mg/l more than 20% of the time in three of the four years of monitoring.

No SAV beds have been found in the Severn since 2005. Benthic populations were impaired with the exception of one site in the lower river that was healthy. Phytoplankton populations were also impaired.

<u>Lower Region</u>

One of the two sub-watersheds in the lower region is moderate priority for restoration efforts through Maryland's Trust Fund Program. Stream health is poor and human population density is moderate. Urban land uses covers 31% of the region and has increased by 9% since 2000. Impervious surfaces cover 6% of this region.

Point sources and agriculture are the most important contributors of nitrogen and phosphorus. Agriculture is the largest source of sediments to the region. There is no water quality monitoring in non-tidal streams of the lower region.

Rhode River

Tidal water monitoring in the Rhode River found worsening conditions due to increasing N but N levels were low enough for nitrogen limitation of algal growth in the summer and fall. Habitat requirements for SAV were met for P, S and algal density but habitat quality was impaired due to poor and worsening water clarity. Bottom dissolved oxygen levels were fair and habitat quality for benthos was fair to good.

Shallow water monitoring indicates turbidity failed to meet good habitat quality requirements at least 70% of the time. Chlorophyll levels passed criteria 65-75% of the time. Summer dissolved oxygen levels in the shallow waters were rarely less than 3 mg/l and passed the 5 mg/l criteria more than 75% of the time.

No SAV beds have been found in the Rhode River since 1978. Benthic populations were impaired at an upstream location but healthy at a location near the river mouth.

West River

Nitrogen levels in West River were low enough for nitrogen limitation of algal growth in the summer and fall. Habitat requirements for SAV were met for P, S and algal density but habitat quality was impaired due to poor and worsening water clarity. Bottom dissolved oxygen levels were fair and habitat quality for benthos was fair to good.

Shallow water monitoring indicated turbidity failed to meet good habitat quality requirements more than 80% of the time. Chlorophyll levels passed criteria at least 85% of the time. Summer dissolved oxygen levels in the shallow waters were rarely less than 3 mg/l and passed the 5 mg/l criteria more than 65% of the time.

No SAV beds have been found in the West River since 2004. Benthic populations were only rarely sampled but were impaired at two locations.

Appendix 1

Land use/Land cover for 2000 and 2010 and Amount of Impervious Surface

Land-use/Land-cover 2000 and 2010 from the Maryland Department of Planning. 2010 data available at www.planning.maryland.gov/OurWork/landUse.shtml. 2000 data available from Maryland Department of Planning, Planning Data Services, (410) 767-4450. Use codes from the Maryland Department of Planning Land Use/ Land Cover Classification Definitions (http://www.planning.maryland.gov/PDF/OurWork/LandUse/AppendixA_LandUseCategories.pdf). Impervious surface calculated from definitions in Cappiella and Brown, Urban Cover and Land Use in the Chesapeake Bay watershed, Center for Watershed Protection, 2001, as referenced in Table 4.1 of a User's Guide to Watershed Planning in Maryland, http://dnr.maryland.gov/watersheds/pubs/userguide.html.

Sub-watershed	Land use/ Land cover	Area in 2000 (sqr miles)	%Total in 2000	Area in 2010 (sqr miles)	%Total in 2010	Area Change (sqr miles)	%Total Area change
Magothy River	AGRICULTURE	0.98	3%	0.44	1%	0.53	1%
	BARREN LAND	0.02	0%	0.01	0%	0.02	0%
	FOREST	10.13	**28%**	7.53	**21%**	2.60	7%
	TRANSPORTATION	0.32	1%	0.33	1%	-0.01	0%
	URBAN	24.22	**68%**	27.41	**77%**	-3.19	-9%
	WETLANDS	0.00	0%	0.00	0%	0.00	0%
	IMPERVIOUS SURFACE	6.15	17%	6.32	18%	-0.16	0%
Severn River	AGRICULTURE	6.84	10%	3.44	5%	3.40	5%
	BARREN LAND	0.07	0%	0.09	0%	-0.02	0%
	FOREST	24.88	**36%**	19.40	**28%**	5.48	8%
	TRANSPORTATION	0.14	0%	1.16	2%	-1.02	-1%
	URBAN	37.30	**54%**	45.16	**65%**	-7.86	**-11%**
	WETLANDS	0.13	0%	0.14	0%	-0.01	0%
	IMPERVIOUS SURFACE	9.19	13%	11.28	16%	-2.09	-3%
South River	AGRICULTURE	10.12	18%	5.81	10%	4.31	8%
	BARREN LAND	0.09	0%	0.05	0%	0.04	0%
	FOREST	27.42	**48%**	22.45	**39%**	4.97	9%
	TRANSPORTATION	0.00	0%	0.70	1%	-0.70	-1%
	URBAN	19.46	**34%**	28.04	**49%**	-8.58	**-15%**
	WETLANDS	0.21	0%	0.27	0%	-0.06	0%
	IMPERVIOUS SURFACE	4.68	8%	6.17	11%	-1.49	-2%
West River	AGRICULTURE	9.24	**36%**	6.90	**27%**	2.34	9%
	BARREN LAND	0.00	0%	0.00	0%	0.00	0%
	FOREST	11.29	**44%**	11.35	**44%**	-0.06	0%
	TRANSPORTATION	0.00	0%	0.00	0%	0.00	0%
	URBAN	4.80	19%	7.09	**28%**	-2.29	-9%
	WETLANDS	0.24	1%	0.22	1%	0.02	0%
	IMPERVIOUS SURFACE	1.07	4%	1.22	5%	-0.16	-1%
West Chesapeake Bay	AGRICULTURE	11.67	14%	8.12	10%	3.56	4%
	BARREN LAND	0.05	0%	0.22	0%	-0.17	0%
	FOREST	46.75	**58%**	42.19	**52%**	4.56	6%
	TRANSPORTATION	0.00	0%	0.07	0%	0.00	0%
	URBAN	20.31	**25%**	28.44	**35%**	-8.13	**-10%**
	WETLANDS	1.91	2%	1.92	2%	0.00	0%
	IMPERVIOUS SURFACE	4.63	6%	5.22	6%	-0.59	-1%
Entire Basin	AGRICULTURE	38.84	13%	24.70	8%	14.14	5%
	BARREN LAND	0.22	0%	0.36	0%	-0.14	0%
	FOREST	120.46	**41%**	102.92	**34%**	17.54	6%
	TRANSPORTATION	0.46	0%	2.26	1%	-1.80	-1%
	URBAN	106.09	**36%**	136.14	**46%**	-30.05	**-10%**
	WETLANDS	2.49	1%	2.55	1%	-0.06	0%
	IMPERVIOUS SURFACE	25.72	9%	30.21	10%	-4.49	-2%

Appendix 2

Delivered Loads to the Lower Western Shore

Phase 5.3 2009 Progress Run 8/25/2010

Chesapeake Bay Program. Accessed January 10, 2012 from http://www.chesapeakebay.net/watershedimplementationplantools.aspx?menuitem=52044 File (ftp://ftp.chesapeakebay.net/Modeling/phase5/Phase53_Loads-Acres-BMPs/MD/ Load_Acres_MDWIP_08252010.xls)

Loads by Land Use Type and Segment

Loads > 20% of total are highlighted in **BOLD.**

River	CBP segment	Category	N load (Million lbs per yr)	% Total N Load	P load (Million lbs per yr)	% Total P Load	Sed load (Million lbs per yr)	% Total Sed Load
Magothy	MAGMH	Agriculture	0.003	1%	0.0003	2%	0.15	7%
		Forest	0.021	9%	0.0014	7%	0.44	**21%**
		Non-tidal Water Depo	0.002	1%	0.0001	0%		
		Septic	0.128	**54%**				
		Urban Runoff	0.066	**28%**	0.0097	**47%**	1.52	**72%**
		Point Source	0.017	7%	0.0092	**44%**	0.00	0%
		TOTAL	**0.236**		**0.0208**		**2.11**	
Severn	SEVMH	Agriculture	0.011	2%	0.0013	3%	0.41	11%
		Forest	0.036	8%	0.0025	5%	0.68	18%
		Non-tidal Water Depo	0.002	0%	0.0001	0%		
		Septic	0.135	**30%**				
		Urban Runoff	0.100	**23%**	0.0164	**32%**	2.62	**70%**
		Point Source	0.161	**36%**	0.0304	**60%**	0.01	0%
		TOTAL	**0.444**		**0.0506**		**3.72**	
South	SOUMH	Agriculture	0.023	10%	0.0030	15%	0.69	**23%**
		Forest	0.041	19%	0.0028	14%	0.60	20%
		Non-tidal Water Depo	0.003	1%	0.0002	1%		
		Septic	0.079	**36%**				
		Urban Runoff	0.066	**30%**	0.0104	**53%**	1.73	**57%**
		Point Source	0.007	3%	0.0034	17%		
		TOTAL	**0.218**		**0.0197**		**3.03**	
Rhode	RHDMH	Agriculture	0.011	**21%**	0.0015	**34%**	0.40	**54%**
		Forest	0.011	**20%**	0.0007	17%	0.19	**25%**
		Non-tidal Water Depo	0.001	2%	0.0001	1%		
		Septic	0.004	7%				
		Urban Runoff	0.007	13%	0.0010	**22%**	0.15	**20%**
		Point Source	0.019	**37%**	0.0011	**26%**	0.00	0%
		TOTAL	**0.053**		**0.0043**		**0.74**	
West	WSTMH	Agriculture	0.014	**37%**	0.0018	**44%**	0.65	**65%**
		Forest	0.009	**23%**	0.0006	15%	0.18	18%
		Non-tidal Water Depo	0.001	2%	0.0000	1%		
		Septic	0.008	**20%**				
		Urban Runoff	0.006	14%	0.0008	19%	0.18	18%
		Point Source	0.002	4%	0.0009	**22%**	0.00	0%
		TOTAL	**0.039**		**0.0042**		**1.00**	

Appendix 3

Station names, locations and descriptions

Long-term tidal water quality stations

Station Name	Location/Depth	Latitude/ Longitude (NAD83 DMS)	Characterizes
WT6.1	Magothy River N of South Ferry Pt, mid-channel at buoy R12 and daymarker G11; 5.0 m.	39° 04.710' N 76° 30.603' W	Lower Estuarine
WT7.1	Severn River, 200 yds upstream of Rt 50/301 bridge and 150 yds off NE shore; 9.0 m.	39° 00.458'N 76° 30.210'W	Lower Estuarine
WT8.1	South River South of Poplar Point at daymarker R16; 9.0 m.	38° 56.976'N 76° 32.766'W	Lower Estuarine
WT8.2	Rhode River between Flat Island and Big Island; 3.0 m.	38° 53.217'N 76° 32.094'W	Lower Estuarine
WT8.3	West River just upstream of daymarker R6; 4.0 m.	38° 50.548'N 76° 32.048'W	Lower Estuarine

Shallow water monitoring locations and dates

Waterbody	Segment	Station Name	Map #	Station	Years deployed	LAT (NAD83)	LONG (NAD83)
Magothy River	MAGMH	Cattail Creek	4	CTT0014	2000 – 2001	39° 05.202’ N	76° 32.789’ W
		Whitehurst	5	CTT0001	2002 – 2003	39° 05.098’ N	76° 31.457’ W
		Stonington	6	XHF3719	2000 – 2003	39° 03.661’ N	76° 28.210’ W
		Additional water quality mapping calibration stations	14	WT6.1	2003	39° 04.710’ N	76° 30.606’ W
			15	XHF3230	2003	39° 03.192’ N	76° 26.964’ W
			16	XHF3339	2003	39° 03.372’ N	76° 26.148’ W
			17	XHF4727	2003	39° 04.722’ N	76° 27.336’ W
			18	XHF5111	2003	39° 05.196’ N	76° 25.974’ W
			19	XHF5340	2003	39° 05.352’ N	76° 25.974’ W
Chesapeake Bay	CB3MH	Sandy Point East Beach	7	XHF0561	2004 – 2007	39° 00.988' N	76° 23.693' W
		Sandy Point South Beach	3	XHF0460	2004 – present	39° 00.450' N	76° 24.020' W
Severn River	SEVMH	Ben Oaks	8	SEV0116	2002 – 2003	39° 04.925’ N	76° 36.661’ W
		Sherwood Forest	9	XHE1973	2002 – 2003	39° 01.897’ N	76° 32.721’ W
		Additional water quality mapping calibration stations	22	WT7.1	2003	39° 00.444’ N	76° 30.330’ W
			23	XGF8027	2003	38° 58.086’ N	76° 27.234’ W
			24	XHE1284	2003	39° 01.248’ N	76° 31.578’ W
			25	XHE2258	2003	39° 02.226’ N	76° 34.170’ W
			26	XHE3170	2003	39° 03.090’ N	76° 33.036’ W
			27	XHF0206	2003	39° 00.174’ N	76° 29.436’ W
South River	SOUMH	Beards Creek	10	XGE7059	2004 – 2006	38° 56.968’ N	76° 34.124’ W
		Cedar Point	11	XGE5984	2005	38° 55.888’ N	76° 31.608’ W
		Harness Creek Upstream	12	ZDM0002	2004 – 2008	38° 56.189’ N	76° 30.443’ W
		Harness Creek Downstream	2	ZDM0001	2004 – 2008	38° 56.159’ N	76° 30.463’ W
		Additional water quality mapping calibration stations	28	WT8.1	2004 – 2006	38° 56.976’ N	76° 32.766’ W
			29	XGE5492	2004 – 2006	38° 55.404’ N	76° 30.792’ W
			30	XGE6281	2004 – 2006	38° 56.214’ N	76° 31.884’ W
			31	XGF5404	2004 – 2006	38° 55.428’ N	76° 29.568’ W
Rhode River	RHDMH	SERC	1	XGE3275	2004 – 2006	38° 53.157’ N	76° 32.489’ W
		Additional water quality mapping calibration stations	20	WT8.2	2004 – 2006	38° 53.220’ N	76° 32.094’ W
			21	XGE2488	2004 – 2006	38° 52.422’ N	76° 31.254’ W
West River	WSTMH	Shady Side	13	XGE0284	2004 – 2006	38° 50.203’ N	76° 31.676’ W
		Additional water quality mapping calibration stations	32	WT8.3	2004 – 2006	38° 50.550’ N	76° 32.046’ W
			33	XGF1780	2004 – 2006	38° 51.636’ N	76° 31.980’ W

Appendix 4

Water and Habitat Quality Data Assessment Methods

Loadings
For USGS methods see http://md.water.usgs.gov/publications/sir-2006-5178/index.html

Current condition- Status

Tidal station nutrient concentrations and physical properties were evaluated to determine the current health of these rivers (status). Relative status was determined for total nitrogen (TN), dissolved inorganic nitrogen (DIN), total phosphorus (TP), dissolved inorganic phosphorus (PO_4), total suspended solids (TSS), algal abundance (as measured by chlorophyll *a*, CHLA) and water clarity (as measured with a Secchi disc) for the 2008-2010 period. For status calculation methods see http://mddnr.chesapeakebay.net/eyesonthebay/documents/ICPRB09-4_StatusMethodPaperMolson2009.pdf.

Results for some parameters are compared with established threshold values to evaluate habitat quality. Summer bottom dissolved oxygen (BDO) is compared to US EPA Chesapeake Bay dissolved oxygen criteria for deep-water seasonal (June- September). Summer dissolved oxygen is considered healthy if levels are 5 mg/l or greater and impaired if levels are less than 3 mg/l. For more details see www.chesapeakebay.net/content/publications/cbp_13142.pdf. DIN is compared to a nitrogen limitation threshold value of less than 0.07 mg/l (Fisher and Gustafson 2002, available online at http://www.hpl.umces.edu/gis_group/Resource%20Limitation/2002_report_27Oct03.htm#es). Submerged aquatic vegetation (SAV) growing season median concentrations for 2008-2010 for PO_4, TSS, CHLA and percent-light through water (PLW) are compared to SAV habitat requirements (Appendix 5), using the methods of Kemp et al. (2004) available online at http://archive.chesapeakebay.net/pubs/sav/savreport.pdf.

Change over time- Trends

Nutrient levels and physical properties were evaluated to determine progress toward improved water quality (trends). For trends calculation methods see http://mddnr.chesapeakebay.net/eyesonthebay/documents/stat_trend_hist.pdf. The following parameters were evaluated: TN, DIN, TP, PO_4, TSS, algal abundance (as measured by chlorophyll *a*, CHLA), water clarity (as measured with a Secchi disc), summer BDO, salinity and water temperature. In order to understand results in the primary parameters, additional parameters were examined including nitrate-nitrite (NO_{23}), ammonium (NH_4) and ratios of nutrient levels (TN:TP, DIN:PO_4) that may explain more about nutrient use by aquatic plants and limitations of available nutrients.

Tidal water quality data were tested for linear trends for 1985-1997, 1999-2010 and 1985-2010. Tests for non-linear trends were also done for 1985-2010 with the tidal water quality data. Trends are significant if $p \leq 0.01$; the text also includes discussion of trends that 'may be' significant when $0.01 < p < 0.05$. Due to a laboratory change in 1998 that affects the tidal water quality data, a step trend may occur for TP, PO_4 and TSS. For these parameters, trends are determined for 1985-1997 and 1999-2010 only.

In addition to annual trends for the various time ranges above, tidal water quality data was tested for seasonal trends for 1999-2010. Seasons tested were spring (March-May), summer (July-September) and SAV growing season (April-October).

Shallow water Temporal Assessment (Percent failure analysis)

Continuous monitoring data were compared to water quality thresholds. Measurements of dissolved oxygen taken during the months of June through September were compared to the USEPA threshold value of 3.2 mg/l for shallow water bay grass use (instantaneous minimum). This time period was used because the summer months typically experience the lowest dissolved oxygen levels and are the most critical for living resources. Chlorophyll and turbidity measurements collected during the SAV growing season of April through October were compared to threshold levels of 15 µg/l and 7 NTU, respectively. Values above these levels can inhibit light penetration through the water column and impact growth of underwater grasses. Percent failures are defined as the percent of values in each year that did not meet the water quality thresholds.

Shallow water Spatial Assessment

Algal density, sediment and nutrient samples were collected from calibration sites on water quality mapping cruises, some of which were also at continuous monitoring sites. In addition, samples were collected at the continuous monitoring sites when the equipment was serviced (approximately every two weeks). All data for a station (water quality mapping calibration and continuous monitoring calibration) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median. Note that the long-term stations include data from long-term and water quality mapping sampling. The median CHLA, TSS, PO_4 and DIN levels and Secchi depths for the April-October SAV growing season were compared to the habitat requirements in the same manner as the long-term tidal data (Appendix 5).

Non-parametric one-way ANOVAs were used to determine if there were differences between stations (SAS Institute software). Where a significant difference was present, a Tukey's Studentized Range (HSD) test was performed to determine which stations were different from each other. Tests were considered significant at $p < 0.05$.

Appendix 5

Submerged Aquatic Vegetation Habitat Requirements

Submerged Aquatic Vegetation (SAV) habitat requirements by salinity regime (from Habitat Requirements for Submerged Aquatic Vegetation in Chesapeake Bay: Water Quality, Light Regime, and Physical-Chemical Factors. W. M. Kemp, R. Batiuk, R. Bartleson, P. Bergstrom, V. Carter, C. L. Gallegos, W. Hunley, L. Karrh, E. W. Koch, J. M. Landwehr, K. A. Moore, L. Murray, M. Naylor, N. B. Rybicki, J. C. Stevenson and D. J. Wilcox. Estuaries. 2004. 27:363–377 available online at http://archive.chesapeakebay.net/pubs/sav/savreport.pdf.).

SAV growing season for all three regimes in Maryland is from April-October. Median seasonal values are compared to the listed habitat requirement to determine if water quality is suitable for SAV growth and survival. Note that the dissolved inorganic nitrogen (DIN) requirement for mesohaline waters exceeds the 0.07 mg/l level where nitrogen limitation of algal growth likely occurs. The more stringent nitrogen limitation DIN level is used for interpretation of habitat quality instead. Due to issues with the model calibration, instead of Percent light at leaf (PLL) water clarity is assessed with percent light through water (PLW) at 1.0 meter depth (L. Karrh, personal communication). PLW can be calculated for the long-term stations that were sampled from 1985-2010. For all stations, Secchi depth can also be used to estimate PLW (L. Karrh, personal communication).

Salinity Regime (ppt)	**Water Column Light Requirement (PLW) (%) or Secchi Depth (m)**	**Total Suspended Solids (mg/l)**	**Plankton Chlorophyll-*a* (µg/l)**	**Dissolved Inorganic Nitrogen (mg/l)**	**Dissolved Inorganic Phosphorus (mg/l)**
Tidal Fresh <0.5 ppt	>13% or 0.725 m	< 15	< 15	Not applicable	< 0.02
Oligohaline 0.5-5 ppt	>13% or 0.725 m	< 15	< 15	Not applicable	< 0.02
Mesohaline 5-18 ppt	>22% or 0.97 m	< 15	< 15	< 0.15 (Nitrogen Limitation < 0.07)	< 0.01

Appendix 6

Current status and long-term tidal water quality trends
Status results for 2008-2010
Trend results from 1985-1997, 1999-2010 and 1985-2010

Data is from the surface layer with the exception of dissolved oxygen, which is from the bottom. Trends for dissolved oxygen are for summer only (June-September). Red colored status and trends results indicate poor or degrading conditions. Green colored status and trends results indicate good or improving conditions. Blue colored status indicates fair status. Blue colored trends indicate decreasing trends where a qualitative assessment (improving or degrading) is not applicable; purple colored trends indicate increasing trends in the same parameters. Grey shading of the 1985-2010 Linear Trend results indicates the non-linear trend is significant and the linear trend results should not be reported. For trends significant at $p \leq 0.01$, results are abbreviated as IMP (improving), DEG (degrading), INC (increasing), DEC (decreasing), U (u-shaped non-linear trend) and INV-U (inverse u-shaped non-linear trend). For trends significant at $0.01 < p < 0.05$, NT (no trend) precedes the abbreviation. NT alone indicates trend is not significant at $p < 0.05$.

Param.	River	Initial 2-yr Median	2008-2010 Median	2008-2010 Status	1985-1997 Linear Trend	1999-2010 Linear Trend	1985-2010 Linear Trend	1985-2010 Non-Lin Trend	Non-linear inflection
TN	MAGOTHY	1.120	0.897	POOR	NT	NT	IMP		
	SEVERN	1.010	0.863	POOR	NT	NT	NT		
	SOUTH	0.900	0.858	POOR	NT	NT	NT		
	RHODE	1.000	0.820	POOR	NT	NT	NT		
	WEST	0.975	0.886	POOR	NT	NT	NT		
DIN	MAGOTHY	0.190	0.102	GOOD	NT	NT	Not evaluated due to lab change		
	SEVERN	0.137	0.119	GOOD	NT	NT			
	SOUTH	0.050	0.041	GOOD	DEG	NT			
	RHODE	0.020	0.034	GOOD	DEG	NTDEG			
	WEST	0.056	0.052	GOOD	DEG	NT			
TP	MAGOTHY	0.059	0.036	GOOD	NT	NT	Not evaluated due to lab change		
	SEVERN	0.061	0.036	GOOD	NT	NTIMP			
	SOUTH	0.084	0.041	FAIR	NT	NTIMP			
	RHODE	0.070	0.042	FAIR	NT	NT			
	WEST	0.053	0.045	POOR	NT	NT			
PO4	MAGOTHY	0.005	0.003	GOOD	*	NTIMP	Not evaluated due to lab change		
	SEVERN	0.005	0.003	GOOD	*	NT			
	SOUTH	0.013	0.003	GOOD	*	NT			
	RHODE	0.005	0.003	GOOD	*	NT			
	WEST	0.005	0.003	GOOD	*	NT			
TSS	MAGOTHY	5.5	4.8	GOOD	DEG	NTIMP	Not evaluated due to lab change		
	SEVERN	7.0	4.6	GOOD	DEG	IMP			
	SOUTH	8.0	5.4	GOOD	NT	IMP			
	RHODE	12.0	9.0	FAIR	NT	NT			
	WEST	12.0	8.0	GOOD	NT	NT			
CHLA	MAGOTHY	12.3	18.4	POOR	NT	NT	DEG		
	SEVERN	14.9	17.9	POOR	NTIMP	NT	NTDEG		
	SOUTH	15.6	17.6	POOR	NT	NT	NT		
	RHODE	13.6	14.2	POOR	NT	NT	NTDEG		
	WEST	12.7	15.0	POOR	NT	NT	NTDEG		

* indicates too much data below detection limit to run trend

Param.	River	Initial 2-yr Median	2008-2010 Median	2008-2010 Status	1985-1997 Linear Trend	1999-2010 Linear Trend	1985-2010 Linear Trend	1985-2010 Non-Lin Trend	Non-linear inflection
SECCHI	**MAGOTHY**	1.0	1.0	**POOR**	NT	NT	**DEG**		
	SEVERN	1.0	1.1	**POOR**	NT	NT	SLOPE=0		
	SOUTH	0.9	1.0	**POOR**	NT	NT	**DEG**		
	RHODE	0.8	0.8	**POOR**	NT	NTDEG	**DEG**		
	WEST	0.8	0.7	**POOR**	NT		**DEG**		
DO	**MAGOTHY**	2.7	1.4	**POOR**	NT	NT	NT		
	SEVERN	3.8	2.3	**FAIR**	NT	NT	NT		
	SOUTH	1.7	1.4	**POOR**	NT	NT	NT		
	RHODE	6.0	5.5	**GOOD**	NT	NT	NTDEG		
	WEST	5.8	5.5	**GOOD**	NT	NT	NT		
WTEMP	**MAGOTHY**	19.4	14.7	**INC**	NT	NT	NT		
	SEVERN	17.5	15.2	**INC**	NT	NT	NT		
	SOUTH	20.8	15.3	**INC**	NT	NT	NT		
	RHODE	21.1	15.5	**INC**	NT	NT	NT		
	WEST	20.6	15.2	**INC**	NT	NT	NT		
SALINITY	**MAGOTHY**	9.0	7.7	**DEC**	**DEC**	NT	NT		
	SEVERN	10.6	9.6	**DEC**	**DEC**	NT	NT		
	SOUTH	10.7	9.8	**DEC**	**DEC**	NT	NTDEC		
	RHODE	11.2	10.2	**DEC**	**DEC**	NT	NTDEC		
	WEST	11.4	10.2	**DEC**	**DEC**	NT	NTDEC		
NH4	**MAGOTHY**	0.028	0.011	**GOOD**	NT	NT			
	SEVERN	0.024	0.008	**GOOD**	NT	NT			
	SOUTH	0.026	0.011	**GOOD**	NT	NT	Not evaluated due to lab change		
	RHODE	0.010	0.009	**GOOD**	NT	NT			
	WEST	0.010	0.009	**GOOD**	NT	NT			
NO23	**MAGOTHY**	0.030	0.069	**GOOD**	NT	NT			
	SEVERN	0.095	0.086	**FAIR**	NT	NT			
	SOUTH	0.010	0.016	**GOOD**	NT	NTDEG	Not evaluated due to lab change		
	RHODE	0.010	0.024	**GOOD**	NT	NTDEG			
	WEST	0.020	0.035	**GOOD**	NT	NT			

Param.	River	Initial 2-yr Median	2008-2010 Median	2008-2010 Status	1985-1997 Linear Trend	1999-2010 Linear Trend	1985-2010 Linear Trend	1985-2010 Non-Lin Trend	Non-linear inflection
TN:TP	**MAGOTHY**	38	57	**INC**	NT	**INC**	Not evaluated due to lab change		
	SEVERN	36	52	**INC**	NT	**INC**			
	SOUTH	26	42	**DEC**	NT	**INC**			
	RHODE	30	35	**DEC**	NT	NTINC			
	WEST	34	39	**DEC**	NT	NTINC			
DIN:PO4	**MAGOTHY**	53	72	**DEC**	NT	NTINC	Not evaluated due to lab change		
	SEVERN	42	67	**DEC**	NT	NTINC			
	SOUTH	7	17	**DEC**	**INC**	**INC**			
	RHODE	9	19	**DEC**	**INC**	**INC**			
	WEST	12	29	**DEC**	NTINC	NTINC			

Appendix 7

Seasonal trends results for long-term tidal water quality data

Seasonal trends results for surface data from 1999-2010. Color codes and abbreviations are the same as used in Appendix 6.

param	River	ANNUAL Jan-Dec	SPRING Mar-May	SUMMER Jun-Sep	SAV Apr-Oct
TN	MAGOTHY	NT	NT	NT	NT
	SEVERN	NT	NT	NT	NT
	SOUTH	NT	NT	NT	NT
	RHODE	NT	NT	NT	NT
	WEST	NT	NT	NT	NT
DIN	MAGOTHY	NT	NT	NT	NT
	SEVERN	NT	NT	NT	NT
	SOUTH	NT	**DEG**	NT	NT
	RHODE	NTDEG	NTDEG	NT	NT
	WEST	NT	NT	NT	NT
TP	MAGOTHY	NT	NT	NT	NT
	SEVERN	NTIMP	NT	NT	NTIMP
	SOUTH	NTIMP	NT	NT	NT
	RHODE	NT	NT	NT	NT
	WEST	NT	NT	NT	NT
PO4	MAGOTHY	NTIMP	NT	NT	NT
	SEVERN	NT	NT	NT	NT
	SOUTH	NT	NT	NT	NT
	RHODE	NT	NT	NT	NT
	WEST	NT	NT	NT	NT
TSS	MAGOTHY	NTIMP	NT	NT	NT
	SEVERN	**IMP**	NTIMP	NTIMP	**IMP**
	SOUTH	**IMP**	NT	NT	NTIMP
	RHODE	NT	NT	NT	NT
	WEST	NT	NT	NT	NT
CHLA	MAGOTHY	NT	NT	NT	NT
	SEVERN	NT	NT	NT	NT
	SOUTH	NT	NT	NT	NT
	RHODE	NT	NT	NT	NT
	WEST	NT	NT	NT	NT
SECCHI	MAGOTHY	NT	NT	NT	NT
	SEVERN	NT	NT	NT	NT
	SOUTH	NT	NT	NT	NT
	RHODE	NTDEG	NT	**DEG**	NTDEG
	WEST		NT	NT	NTDEG
WTEMP	MAGOTHY	NT	NT	NT	NT
	SEVERN	NT	NT	NT	NT
	SOUTH	NT	NT	NT	NT
	RHODE	NT	NT	NT	NT
	WEST	NT	NT	NT	NT
SALINITY	MAGOTHY	NT	NT	NT	NT
	SEVERN	NT	NTDEC	NT	NT
	SOUTH	NT	NTDEC	NT	NT
	RHODE	NT	NT	NT	NT
	WEST	NT	NT	NT	NT

Appendix 8

Shallow water monitoring water and habitat quality

Temporal Assessment- Percent failures

Continuous monitoring data for the years 2000-2010. Instantaneous measurements of dissolved oxygen taken during June through September were compared to threshold value 3.2 mg/l. Chlorophyll and turbidity measurements collected during the SAV growing were compared to threshold levels of 15µg/l and 7 NTU, respectively. The percent of values in each year that did not meet the water quality thresholds are presented as "percent failures".

Station	Location	Year	Dissolved Oxygen Threshold % < 3.2 mg/l	Chlorophyll Threshold % > 15 ug/l	Turbidity Threshold % > 7 NTU
CTT0014	*Magothy River*	2000	91.76	67.13	99.19
	Cattail Creek	2001	82.86	76.32	92.74
CTT0001	*Magothy River*	2002	3.46	79.68	41.69
	Whitehurst	2003	1.24	65.69	32.87
XHF3719	*Magothy River*	2000	0.39	66.66	52.29
	Stonington	2001	0.89	77.77	66.73
		2002	1.42	84.26	49.87
		2003	1.03	70.91	81.03
XHF0561	*Chesapeake Bay*	2004	0.23	12.59	86.85
	Sandy Point	2005	1.12	20.60	80.41
	East Beach	2006	0.45	28.89	65.61
		2007	0.66	43.28	72.38
XHF0460	*Chesapeake Bay*	2004	0.23	20.91	82.34
	Sandy Point	2005	0.00	30.22	74.37
	South Beach	2006	0.00	32.71	60.82
		2007	0.14	50.77	72.74
		2008	0.00	38.89	71.91
		2009	0.00	36.87	59.93
		2010	0.52	24.75	62.26
SEV0116	*Severn River*	2002	25.04	93.41	95.38
	Ben Oaks	2003	25.49	84.04	83.39
XHE1973	*Severn River*	2002	2.08	34.07	5.56
	Sherwood Forest	2003	0.97	41.75	17.18
XGE7059	*South River*	2004	2.26	61.64	25.54
	Beards Creek	2005	2.75	44.45	19.36
		2006	1.45	59.48	14.45
XGE5984	*South River* Cedar Point	2005	1.17	32.24	41.41
ZDM0002	*South River*	2004	5.66	63.41	61.33
	Harness Creek	2006	26.07	58.77	69.07
	Upstream	2007	70.08	64.35	85.97
		2008	19.18	82.28	58.65
ZDM0001	*South River*	2004	6.12	64.53	58.55
	Harness Creek	2006	7.54	62.02	60.61
	Downstream	2007	20.15	81.71	63.37
		2008	8.34	76.60	52.90
XGE3275	*Rhode River*	2004	3.28	78.53	88.46
	SERC	2005	2.59	44.27	80.53
		2006	5.14	67.18	68.65
XGE0284	*West River*	2004	1.23	41.67	87.95
	Shady Side	2005	4.56	65.85	89.31
		2006	9.44	49.04	81.05

< 10 % failure

40 - 70 % failure

10 - 40 % failure

> 70 % failure

Spatial Assessment

Shallow water monitoring data for 2003 compared to SAV habitat requirements in the Magothy and Severn rivers.
All data for a station (water quality mapping and continuous monitoring) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median, which was compared to habitat requirements (Appendix 5). Note that the long-term stations include data from long-term and water quality mapping sampling.

	STATION		map#	year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		Secchi Depth		Dissolved		Salinity		TN	TP	wtemp
MAGOTHY RIVER	Whitehurst	CTT0001	5	2003	25.6	FAIL	7.8	MEET	0.224	FAIL	0.0032	MEET	0.6	FAIL	8.5	MEET	4.1	OH	1.172	0.0479	21.6
	long-term	WT6.1	14	2003	32.3	FAIL	6.6	MEET	0.125	FAIL	0.0051	MEET	0.7	FAIL	8.7	MEET	4.9	OH	1.038	0.0441	23.3
	Stonington	XHF3719	6	2003	23.1	FAIL	10.5	MEET	0.208	FAIL	0.0039	MEET	0.7	FAIL	9.4	MEET	5.0	OH	1.018	0.0554	21.3
		XHF4727	17	2003	16.6	FAIL	10.0	MEET	0.216	FAIL	0.0060	MEET	0.6	FAIL	7.5	MEET	5.7	MH	0.893	0.0514	22.8
		XHF3230	15	2003	18.7	FAIL	7.5	MEET	0.237	FAIL	0.0052	MEET	0.7	FAIL	8.3	MEET	5.4	MH	1.044	0.0458	23.0
		XHF3339	16	2003	22.8	FAIL	9.0	MEET	0.299	FAIL	0.0044	MEET	0.7	FAIL	7.6	MEET	5.6	MH	1.060	0.0506	22.9
		XHF5111	18	2003	17.6	FAIL	7.3	MEET	0.151	FAIL	0.0027	MEET	0.7	FAIL	8.5	MEET	5.4	MH	0.975	0.0420	23.3
		XHF5340	19	2003	16.1	FAIL	9.0	MEET	0.112	FAIL	0.0034	MEET	0.6	FAIL	8.3	MEET	5.4	MH	0.958	0.0424	23.0
SEVERN RIVER	Ben Oaks	SEV0116	8	2003	25.4	FAIL	11.0	MEET	0.369	FAIL	0.0053	MEET	0.6	FAIL	6.3	MEET	4.2	OH	1.262	0.0640	20.4
		XHE3170	26	2003	19.0	FAIL	7.2	MEET	0.073	FAIL	0.0042	MEET	0.8	FAIL	8.9	MEET	6.1	MH	0.837	0.0320	20.1
		XHE2258	25	2003	21.1	FAIL	6.4	MEET	0.066	MEET	0.0032	MEET	0.9	FAIL	8.5	MEET	6.0	MH	0.805	0.0382	20.8
	Sherwood Forest	XHE1973	9	2003	18.3	FAIL	6.8	MEET	0.103	FAIL	0.0032	MEET	0.8	FAIL	9.0	MEET	5.8	MH	0.876	0.0409	21.4
		XHE1284	24	2003	20.8	FAIL	8.5	MEET	0.207	FAIL	0.0025	MEET	0.8	FAIL	9.0	MEET	6.3	MH	0.936	0.0404	18.3
	long-term	WT7.1	22	2003	27.7	FAIL	8.6	MEET	0.105	FAIL	0.0038	MEET	0.8	FAIL	8.4	MEET	6.4	MH	0.973	0.0431	21.8
		XHF0206	27	2003	18.1	FAIL	7.7	MEET	0.179	FAIL	0.0027	MEET	0.8	FAIL	8.4	MEET	6.6	MH	0.922	0.0323	19.7
		XGF8027	23	2003	12.6	MEET	8.8	MEET	0.298	FAIL	0.0046	MEET	0.8	FAIL	8.7	MEET	7.5	MH	0.975	0.0411	22.2

Shallow water monitoring data for 2004-2006 compared to SAV habitat requirements in the South, Rhode and West rivers.
All data for a station (water quality mapping and continuous monitoring) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median, which was compared to habitat requirements (Appendix 5). Note that the long-term stations include data from long-term and water quality mapping sampling.

	STATION		map#	year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		Secchi Depth		Dissolved		Salinity		TN	TP	wtemp
SOUTH RIVER	Beards Creek	XGE7059	10	2004	26.4	FAIL	9.7	MEET	0.070	MEET	0.0038	MEET	0.7	FAIL	8.0	MEET	5.6	MH	0.993	0.0579	25.3
				2005	23.1	FAIL	8.5	MEET	0.021	MEET	0.0054	MEET	0.6	FAIL	7.9	MEET	8.4	MH	0.943	0.0652	24.5
				2006	22.9	FAIL	7.3	MEET	0.040	MEET	0.0059	MEET	0.6	FAIL	7.6	MEET	9.3	MH	0.873	0.0645	23.3
		WT8.1	28	2004	22.8	FAIL	6.8	MEET	0.177	FAIL	0.0045	MEET	0.6	FAIL	8.4	MEET	5.9	MH	0.975	0.0496	25.0
				2005	22.8	FAIL	5.0	MEET	0.045	MEET	0.0046	MEET	0.7	FAIL	8.1	MEET	8.9	MH	0.931	0.0564	24.8
				2006	24.3	FAIL	6.8	MEET	0.019	MEET	0.0049	MEET	0.8	FAIL	8.6	MEET	9.6	MH	0.928	0.0572	23.8
		XGE6281	30	2004	20.9	FAIL	6.4	MEET	0.206	FAIL	0.0040	MEET	0.7	FAIL	7.9	MEET	6.4	MH	0.909	0.0397	24.1
				2005	20.6	FAIL	6.0	MEET	0.048	MEET	0.0033	MEET	0.7	FAIL	8.1	MEET	9.3	MH	0.941	0.0552	24.4
				2006	15.3	FAIL	4.8	MEET	0.054	MEET	0.0054	MEET	0.9	FAIL	7.3	MEET	10.0	MH	0.812	0.0478	23.7
	Cedar Point	XGE5984	11	2005	17.0	FAIL	11.0	MEET	0.029	MEET	0.0053	MEET	0.6	FAIL	7.4	MEET	9.5	MH	0.895	0.0509	23.6
		XGE5492	29	2004	21.5	FAIL	10.6	MEET	0.261	FAIL	0.0027	MEET	0.7	FAIL	7.9	MEET	6.3	MH	0.890	0.0382	24.1
				2005	16.8	FAIL	6.4	MEET	0.022	MEET	0.0058	MEET	0.7	FAIL	8.0	MEET	9.6	MH	0.800	0.0355	24.1
				2006	17.2	FAIL	4.8	MEET	0.076	FAIL	0.0056	MEET	0.8	FAIL	7.7	MEET	10.2	MH	0.830	0.0457	24.2
		XGF5404	31	2004	16.7	FAIL	5.8	MEET	0.357	FAIL	0.0023	MEET	0.8	FAIL	7.4	MEET	6.7	MH	0.971	0.0332	24.0
				2005	12.0	MEET	7.0	MEET	0.019	MEET	0.0031	MEET	0.6	FAIL	8.7	MEET	9.8	MH	0.782	0.0363	24.0
				2006	15.7	FAIL	9.5	MEET	0.093	FAIL	0.0058	MEET	0.6	FAIL	7.7	MEET	11.3	MH	0.819	0.0468	23.9
RHODE RIVER	SERC	XGE3275	1	2004	35.6	FAIL	20.0	FAIL	0.082	FAIL	0.0053	MEET	0.5	FAIL	6.3	MEET	7.2	MH	1.136	0.0839	25.6
				2005	18.9	FAIL	16.7	FAIL	0.041	MEET	0.0052	MEET	0.4	FAIL	6.8	MEET	9.7	MH	1.063	0.0699	24.3
				2006	24.0	FAIL	18.0	FAIL	0.038	MEET	0.0067	MEET	0.5	FAIL	6.8	MEET	10.1	MH	1.105	0.0721	24.3
		WT8.2	20	2004	19.1	FAIL	11.0	MEET	0.116	FAIL	0.0048	MEET	0.6	FAIL	7.0	MEET	6.4	MH	1.109	0.0622	25.4
				2005	19.8	FAIL	11.8	MEET	0.033	MEET	0.0044	MEET	0.6	FAIL	8.0	MEET	10.0	MH	0.979	0.0579	24.1
				2006	19.4	FAIL	8.9	MEET	0.031	MEET	0.0058	MEET	0.6	FAIL	7.5	MEET	10.5	MH	1.036	0.0573	25.1
		XGE2488	21	2004	13.8	MEET	10.0	MEET	0.268	FAIL	0.0033	MEET	0.6	FAIL	7.4	MEET	7.3	MH	0.968	0.0354	25.0
				2005	15.0	MEET	9.5	MEET	0.041	MEET	0.0042	MEET	0.7	FAIL	7.9	MEET	10.4	MH	0.930	0.0591	23.8
				2006	19.1	FAIL	9.3	MEET	0.077	FAIL	0.0061	MEET	0.8	FAIL	7.5	MEET	11.3	MH	0.944	0.0503	24.9
		XGF1780	33	2004	12.0	MEET	7.2	MEET	0.275	FAIL	0.0026	MEET	0.6	FAIL	7.6	MEET	7.9	MH	0.901	0.0369	24.5
				2005	15.3	FAIL	12.9	MEET	0.066	MEET	0.0036	MEET	0.7	FAIL	7.7	MEET	11.0	MH	0.909	0.0481	23.5
				2006	19.8	FAIL	8.5	MEET	0.043	MEET	0.0071	MEET	0.5	FAIL	7.1	MEET	10.5	MH	0.908	0.0446	25.3
WEST RIVER	Shady Side	XGE0284	13	2004	10.1	MEET	16.7	FAIL	0.289	FAIL	0.0049	MEET	0.6	FAIL	6.0	MEET	7.1	MH	1.010	0.0473	25.2
				2005	14.6	MEET	20.2	FAIL	0.113	FAIL	0.0054	MEET	0.4	FAIL	6.6	MEET	10.2	MH	0.983	0.0537	23.6
				2006	15.0	MEET	25.3	FAIL	0.061	MEET	0.0057	MEET	0.5	FAIL	6.4	MEET	10.2	MH	0.969	0.0586	24.6
	long-term	WT8.3	32	2004	16.1	FAIL	9.8	MEET	0.308	FAIL	0.0049	MEET	0.6	FAIL	7.4	MEET	6.4	MH	0.984	0.0441	23.9
				2005	16.4	FAIL	12.0	MEET	0.076	FAIL	0.0043	MEET	0.6	FAIL	7.6	MEET	10.2	MH	0.979	0.0559	23.8
				2006	19.4	FAIL	15.5	FAIL	0.064	MEET	0.0048	MEET	0.5	FAIL	7.2	MEET	10.6	MH	1.030	0.0539	23.9